

»» THE MOST POWERFUL THINGS IN THE WORLD

POPULAR MECHANICS

HOW YOUR WORLD WORKS



We drove Bigfoot!
Page 68

The *Challenger* Disaster: 30 Years Later

THE DARKEST DAY
IN SPACE EXPLORATION,
TOLD BY THE
PEOPLE WHO WERE THERE



×

OSCAR SPECIAL:
The Geniuses
Behind
The Movies
PAGE 82

×

**BORDER
SECURITY**
The New
High-Tech
Fence
PAGE 9

×

**WANNA GO
ICE FISHING?**
A Beginner's
Guide
PAGE 37

Cape Canaveral,
Florida,
January 28, 1986



Eddie Redmayne
Stand Up To Cancer Ambassador

1600 PEOPLE WILL DIE TODAY WE CAN'T ACT FAST ENOUGH

When you give to Stand Up To Cancer you enable top researchers and doctors to work together — in real time — to accelerate breakthrough treatments for patients today.

ACT NOW. SAVE LIVES.

Please visit SU2C.org or text STAND to 40202 to give \$10 now.

Photo by Greg Williams.

Stand Up To Cancer is a program of the Entertainment Industry Foundation (EIF), a 501(c)(3) charitable organization. \$10.00 donation to EIF-SU2C. Charges will appear on your wireless bill, or be deducted from your prepaid balance. All purchases must be authorized by account holder. Must be 18 years of age or have parental permission to participate. Msg&Data Rates May Apply. Text STOP to 40202 to STOP. Text HELP to 40202 for HELP. Full Terms: mGive.org/T. Privacy Policy: mGive.org/P



Proven Leaders.

Team Players.

Future Colleagues.



The right team can take a business to the next level.

The experience veterans gain in the military makes them ideal employees in the civilian workforce. Resume Engine translates military experience, training, and honors into relatable job qualifications and allows recruiters to search for veteran candidates at no cost. Veterans can use this free tool to create and share a strong resume with employers nationwide.

Start searching for your next team member today.

ResumeEngine.org

HIRING OUR HEROES.
U.S. CHAMBER OF COMMERCE FOUNDATION

 **TOYOTA**
Let's Go Places

CONTENTS

FEBRUARY • 2016

- 4 From the Editor
- 6 Calendar
- 7 The Reader Page

HOW YOUR WORLD WORKS

- 9 The new technology that's making our border more secure
- 12 What it really means to remaster an album
- 14 Using photography to fight ISIS's destruction
- 16 The second-most-famous drink in Boston
- 18 Super Bowl technology gets, well, super
- 20 **Things Come Apart:** Jackhammer
- 22 Great Unknowns

KNOW-HOW

- 27 The house that teens built
- 30 **Tool Test:** Band saws, flashlights, and work gloves
- 34 Shop Notes
- 37 **Getting Started In:** Ice fishing
- 40 Ask Roy

DRIVING

- 43 VW didn't doom diesel. Diesel did.
- 46 An 11-hour road trip in a \$500,000 Italian sports car
- 48 **Reviews:** New rides from Honda, Land Rover, and Chevrolet

A BEAUTIFUL THING

- 52 **Woodstock Soapstone's Hybrid Woodstove**
Warm your house, save the planet

PROJECT

- 91 Build your own firewood rack

POPULAR MECHANICS FOR KIDS

- 99 How to make a snowball-slinging catapult



54
JANUARY 28, 1986

On the 30th anniversary of the space shuttle *Challenger* disaster, the men and women who were on the ground, in front of the camera, and in the White House that day look back to remember—and to wonder why it went so wrong.

BY MARGARET LAZARUS DEAN

Christa McAuliffe would have been the first teacher to go to space.



64

THE MOST POWERFUL THINGS IN THE WORLD

A highly selective look at the strongest, fastest, most impressive machines in the world according to horsepower, impact, energy, and our occasional whim. Including: cars, boats, lasers, and dung beetles.



76

SHORT SKIRTS, FULL HEADS, CAN'T LOSE

Meet the NFL and NBA cheerleaders who moonlight as NASA scientists and Parkinson's researchers—and who are leading the rallying cry for STEM education.

BY ALLISON
WRIGHT



80

HOW IT WORKS: EXTREME AIRCRAFT MAINTENANCE

The massive plane disassembly that keeps you safe at 35,000 feet.

BY KEVIN DUPZYK



82

POPULAR MECHANICS GOES TO THE OSCARS

The Academy's lesser-known Scientific and Technical Awards recognize the technology and creators that make movies possible. This year, an in-depth look at the Other Oscars. Plus: The Incredibly Special Effects Awards!

From the Editor

TO-DO LISTS

February. First issue of Popular Mechanics to hit your mailbox (or your friendly neighborhood airport newsstand) in the new year. The beginning of a new year, for a lot of people, is full of excitement. Possibility! I find it daunting. We make lists of things we want to accomplish, but there's too much to do and not enough time. And then this reminds me of all the things I need to accomplish in my daily life, and then I get despondent, and then I look for the bourbon.

Take the other weekend. It was unseasonably warm, so I planned on replacing the broken windowpane in the mudroom that had shattered when my son kicked his sneaker off. And the windowpane that my other son broke when he was knocking on it too hard, trying to get my attention while I was outside using the snowblower. And also the other one that was broken when we bought the house.

I also thought I would sneak in some other quick chores: finally hanging the cedar flower boxes I built for my wife *last spring*, stocking the log rack on the porch with wood from the pile out back, and painting the trim on the Mudroom Project That Will Never End.

How much of that did I get done? None of it. Not even the windows. My measurements for the glass were a sixteenth of an inch off, and because you can't bend glass, I had to go back to the hardware store to get the panes recut, and by that time I had to take the boys to soccer. The first part of the day was blown.

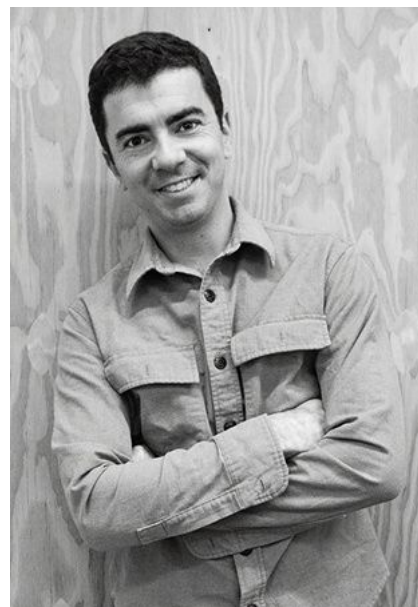
So I thought: After soccer. I'll at least do the windowpanes after soccer. That was around 4:30. Getting dark. I'm up on the ladder, headlamp ablaze, new windowpane in hand,

glazing compound getting stiff because now it's getting cold. But I'm all ready to go and—"Dad?"

My son (the one with the flying sneaker). He had a school project he needed help with. They had to build a Native American community, and he had drawn an elaborate plan to build the miniature scene—longhouses, bonfires, a river, hide tanning—on a piece of wood.

I breathed in deep, inhaling the fumes of the glazing compound. I climbed down the ladder, packed up my little window-fixing kit and put it away till the next weekend. My son and I rummaged through the barn for a perfect piece of plywood, which I cut to size. We made a frame around it, which he measured, glued, and clamped.

Things work out, I guess. They'll work out this year. We'll all accomplish what we need to accomplish. Because even as the list of undone tasks grew and the sun set, and even though the flower boxes are still unhung and the mudroom still isn't finished, I realized as I watched my son working away on his school project, sawdust on his elbows, that on that busy Sunday I had done everything that needed to get done.



[Signature]

RYAN D'AGOSTINO
Editor in Chief

POPULAR MECHANICS SINCE 1902

Mobile Editions: Mobile Editions Editor **Tom Losinski** • **Popular Mechanics Interactive:** Producer **Jeff Zinn** • **Published by Hearst Communications, Inc.**, President & Chief Executive Officer **Steven R. Swartz** • Chairman **William R. Hearst III** • Executive Vice Chairman **Frank A. Bennack, Jr.** • **Hearst Magazines Division:** President **David Carey** • President, Marketing & Publishing Director **Michael Clinton** • Editorial Director **Ellen Levine** • Publishing Consultant **Gilbert C. Maurer** • Publishing Consultant **Mark F. Miller**

Publisher, Chief Revenue Officer **Cameron Connors** • Advertising Director **Adam C. Dub** • Executive Director, Group Marketing **Lisa Boyars** • **Advertising Sales Offices:** **NEW YORK:** East Coast Automotive Director **Cameron Alberg** • Integrated Account Managers **Sara Schiano**, **Loren Black** • East Coast Digital Sales Managers **Drew Osinski**, **Brett Fickler** • Assistant **Vincent Carbone** • **LOS ANGELES:** Integrated California Sales Director **Anthony P. Imperato** • Integration Associate **Michelle Nelson** • Assistant **Michael Okubo** • **SAN FRANCISCO:** Steve Thompson, **William G. Smith**, **Mediacentric, Inc.** • **CHICAGO:** Integrated Midwest Director **Kim Skipper** • Integrated Sales Manager **Paul Fruin** • Assistant **Yvonne Villareal** • **DETROIT:** Integrated Sales Director **Mark Fikany** • Assistant **Toni Starrs** • **DALLAS:** **Patty Rudolph** PR 4.0 Media • **Hearst Direct Media:** Sales Manager **Brad Gettelfinger** • Account Manager **John Stankewitz** • **Marketing Solutions:** Senior Marketing Director **Jason Graham** • Associate Marketing Director **Amanda Luginbill** • Marketing Manager **Michael Coopersmith** • Associate Integrated Marketing Manager **Holly Mascaro** • Integrated Marketing Coordinator **Scott Topel** • Digital Marketing Director **Kelley Gudahl** • Digital Marketing Manager **Anthony Fairall** • **Creative Solutions:** Executive Creative Director, Group Marketing **Jana Nesbitt Gale** • Art Directors **Elena Mortorano**, **Michael B. Sarry** • **Administration:** Advertising Services Director **Regina Wall** • Advertising Services Coordinator **Rebecca Taroon** • Executive Assistant to the Publisher **Sara Blad** • Centralized Billing Services Coordinator **Christa Calaban** • **Production:** Group Production Director **Chuck Lodato** • Group Production Manager **Lynn Onoyeyan Scaglione** • Associate Production Manager **Celeste Madhere** • **Circulation:** Consumer Marketing Director **William Carter** • **Hearst Men's Group:** Senior Vice President & Publishing Director **Jack Essig** • Associate Publisher & Group Marketing Director **Jill Meenaghan** • General Manager **Samantha Irwin** • Executive Director, Group Strategy & Development **Dawn Sheggeby** • Senior Financial Analyst **Naiobe Mayo**





KITANDACE.COM

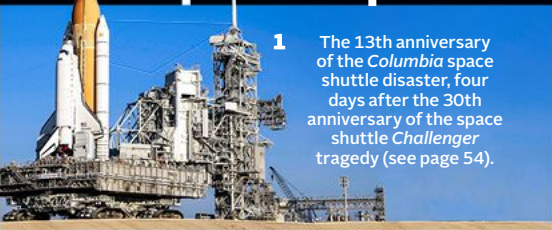


KIT ACE

NOT FOR YOGA

Calendar FEBRUARY

How to get the most out of your month.

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
	1 The 13th anniversary of the <i>Columbia</i> space shuttle disaster, four days after the 30th anniversary of the space shuttle <i>Challenger</i> tragedy (see page 54).		3		5 If you're in the market, the week before the Super Bowl is one of the best times of the year to buy a new TV. Good sales.	6 Outdoor hockey tournaments start popping up around the country this weekend and next. Find one to play in, or watch, at labattblue-pondhockey.com .
7 Super Bowl 50. A lot has changed since the first one. See our review of the broadcast's new technology on page 18.	8 	9 The March issue of <i>Popular Mechanics</i> hits newsstands.	IN THE MARCH ISSUE Our annual survival guide teaches you how to properly hunker down or flee for the hills. Plus, how one stranded man survived on an ice floe, which he shared with a polar bear, in the Arctic Circle.		12 	13 Movie geniuses get recognized at the Academy's Scientific and Technical Awards tonight. Learn more on page 82.
14 HBO's <i>Vinyl</i> premieres. And don't forget, it's Valentine's Day—handmade gifts trumps store-bought gifts.	15 The Grammy Awards. Find someone new to add to your workshop playlist. Perhaps more importantly, it's Presidents' Day.	16 	18 What's more fun than taking a kid to a car show? A boat show! Detroit's 58th annual show is this week, as is an expo in Boston.	19 Go see <i>Triple 9</i> , a tense heist film of crooked cops, the Russian mafia, and <i>True Detective</i> —style Woody Harrelson.	20 Use the cold weather as an excuse to stay indoors and get some chores done.	
21 Nascar's best drivers endure a grueling 200 laps during the Daytona 500. Best to tune in just for the last ten.		23	24 Normally, there would be 310 days left in the year. But it's a leap year, so...311.	25	26 The superhero flick gets a historical twist in the mythology-inspired <i>Gods of Egypt</i> .	27 
28 The Academy Awards airs to remind you of all the movies you said you were going to go see this year.	29 Use Leap Day to check up on things that need upgrading or replacing, like smoke alarms, fire extinguishers, car batteries, and Brita filters.		2	3		5

FRI
2/5

THE BEST TIME TO BUY

In 2013 nearly a quarter of HDTV owners in the U.S. bought their TVs for the specific purpose of watching the Super Bowl, according

to a study by the Consumer Technology Association. If you're one of those enthusiasts, or if you're just looking to upgrade, the week before the big game is actually an ideal time to buy. Many retailers view this week as a last chance to get old models off the floor, since new TV models tend to be released in the spring. Last year, 55-inch and larger LED TVs from the likes of Samsung and Vizio sold for less than \$1,000 at Walmart and on Amazon.

SUN
2/14

THE TV RECOMMENDATION

HBO's newest drama series *Vinyl* is executive produced by Martin Scorsese and Mick Jagger, and writ-

ten and created by Terence Winter, who brought us *The Sopranos*, *The Wolf of Wall Street*, and *Boardwalk Empire*. A paean to the analog days of 1970s New York, the show follows the exploits of a struggling record-company president at a musical crossroads of disco, punk, and early hip-hop. Expect signature Scorsese violence and a soundtrack that will have you dusting off your dad's record collection.

SAT
2/20

HOW TO GET STUFF DONE IN WINTER

Since most of us are trapped indoors anyway, now's the

time to get some minor indoor maintenance out of the way. That means breaking out the WD-40 and grease. A rule of thumb: If you want to keep something lubricated without oil running off it, such as a hinge pin on a squeaky door, use a dab of grease. Save oil sprays for penetrating hard-to-reach places, like window chains.

The Reader Page

FREE MONEY: We give \$100 for reader projects that we publish, and \$50 for original reader tips that we run. You can send both to editor@popularmechanics.com.



A HOT-ROD-INSPIRED SMOKER

Josh Wolfe of Linton, Indiana, does what we all do—watch cooking shows and pine for the food. After watching a few too many episodes of *BBQ With Franklin* on PBS, Josh wanted in. Since smokers are expensive, he decided to use his 20 years of experience as a maintenance worker to build his own. An admitted junker, Josh had an office-file cart on hand that he had salvaged from a dumpster. The bottom shelf fit perfectly as

a lid once he added a set of hinges. For the firebox he cut a door in the side of an empty propane tank and bored a hole on top where the nozzle connects to the pipe. To get the decorative flames for the look of a classic rat-rod-style hot rod, Josh used a plasma torch to freehand-cut an old stainless-steel plate and applied it to the lid. He finished the smoker in time for his birthday, which he celebrated by spending ten hours smoking five racks of ribs.

LETTER OF THE MONTH

YOU'RE ONLY OFF BY A COUPLE HUNDRED MILLION . . .

It costs \$500,000 to restore a spacesuit? (“How Your World Works,” November) For that price it ought to include a trip to the moon and back to retrieve all the items left behind there too.

—
Joe Morgan, Castle Rock, Colorado



TALK TO US!

You can always get our attention and share your questions, projects, or smoked meats on Twitter and Instagram using **#popularmechanics**.

Letters to the editor can be emailed to editor@popularmechanics.com. Include your full name and address. Letters may be edited for length and clarity. **CUSTOMER SERVICE/SUBSCRIPTIONS** online: service.popularmechanics.com; email: popcustserv@cdsfulfillment.com; mail: Popular Mechanics, P.O. Box 6000, Harlan, IA 51593; **subscribe:** subscribe.popularmechanics.com.

WHICH COVER IS WEIRDER?

THE SECOND-ROUND RESULTS

October 1933



77%

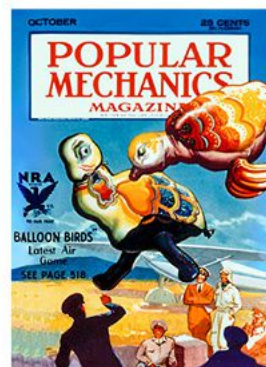
July 1957



23%

ROUND THREE!

A October 1933



B July 1999



Cast your vote now for Cover A or Cover B. The winning cover will square off against another challenger in the April issue.

- Email your vote to editor@popularmechanics.com.
- Or tweet it to [@popmech](https://twitter.com/popmech) using **#weirdcover**.



NORTH AMERICAN INTERNATIONAL
AUTO SHOW

2016 NORTH AMERICAN INTERNATIONAL AUTO SHOW

PRESS PREVIEW: JANUARY 11-12 | INDUSTRY PREVIEW: JANUARY 13-14
CHARITY PREVIEW: JANUARY 15 | PUBLIC SHOW: JANUARY 16-24

All roads lead to Detroit. As the automotive industry drives into the future, Detroit remains in the driver's seat and NAIAS is the destination where next-generation products and technologies continue to make their world debuts.



LIKEAUTOSHOW.COM



TWITTER.COM/NAIASDETROIT



INSTAGRAM.COM/NAIASDETROIT



HOW YOUR WORLD WORKS

A STRIKES | RUM | COLTRANE | A JACKHAMMER

BORDER CONTROL

The Invisible Wall

A new detection system in Arizona promises to give border-control agents more insight into the threats they face before they face them. And it's only the beginning.

BY MITCH MOXLEY

Agent Jose Verdugo's workplace is vast: 1,100 square miles of hilly, sandy terrain surrounding Nogales, Arizona, the second-largest border-patrol station in the country. Depending on the day's assignment, he'll hike trails or drive along the boundary between the United States and Mexico. Some days he investigates human trafficking or drug smuggling. (Half of the marijuana that crosses the southwest border is captured in the Tucson sector, where Nogales is situated.) Other days Verdugo investigates a suspicious blip on a radar system that often

turns out to be foul weather, or a rancher tending his land, or a stray cow.

Over the years, U.S. Customs and Border Protection (CBP) has used a series of strategies, some more effective than others, to monitor huge swaths of rugged terrain along the border. It needed a solution that would prevent agents like Verdugo from being deployed for false alarms, so they could chase and investigate narcos rather than livestock and be prepared for what they encountered when they caught up. This would require permanent sensors that could provide a clear picture to agents back at the station of what was happening in the field.





← The Integrated Fixed Towers system could improve security and reduce the use of excessive force along the U.S.–Mexico border.

The Integrated Fixed Towers (IFT) system, which includes radar and day and night cameras mounted on a series of towers along the border, promises to solve the problem. The radar and cameras transmit data over microwave link to the Nogales station, where agents determine an appropriate course of action.

The system, which enables agents to accurately monitor areas previously unobserved, is, Verdugo says, like “turning on a light switch” along the dark, mysterious border.

The IFT is only the latest of the government’s attempts to cover the southwestern border with sensors capable of detecting unlawful crossings. The previous setup, known as SBInet, was a network of newly designed radar, cameras, and heat and motion detectors, which was supposed to allow border-patrol agents to work from a common operational picture. Boeing won the contract in 2006, and the system was initiated across 53 miles of Arizona’s Mexico border.

It quickly became a boondoggle. Total acquisition costs rose to a projected \$1.6 billion, a staggering \$1.4 billion more than initial estimated costs, according to the Government Accountability Office. It also didn’t really work. The main problem was communication—the information transmitted to the command center was unreliable. It didn’t operate well in the varied terrain of the Tucson sector, and was often triggered by bad weather, leading to false positives. In 2010, as costs rose, then Homeland Security secretary Janet Napolitano halted the program and asked border patrol to start over. “One of the lessons of SBInet was you’re better off going small than big, and you’re better off going off-the-shelf than innovative,” says Christopher Wilson, a border-security expert and deputy director of the Mexico Institute at the Woodrow Wilson Center.

Border-patrol officials came to the same conclusion and sought out preexisting, tested technology.

With radar, day and night cameras, and thermal imaging, the new system is like “turning on a light switch” along the dark, mysterious border.

The new approach, announced in 2011, would combine proven mobile surveillance, thermal imaging, and tower-mounted video technology. The request for IFT proposals called for sensors able to detect “a single, walking, average-sized adult” and provide sufficiently high-resolution video of that adult at a range of up to 7.5 miles in daylight and darkness.

The biggest defense contractors—including General Dynamics, Lockheed Martin, and Raytheon—all competed for the \$145 million contract, which was awarded to Elbit Systems of America, the Fort Worth, Texas–based subsidiary of Israel’s Elbit Systems. Elbit has deployed hundreds of miles of border-monitoring systems between

Israel and Palestine and also provided multisensor surveillance systems along Israel’s border with Gaza and Egypt. As of July, Elbit had completed construction in Nogales, and in September it crossed a major hurdle when the IFT system, tested by border-security agents, demonstrated the capacity to detect, track, and classify movement on the border. In other words, it works. Elbit’s system is so specific that it can determine whether an individual is carrying a backpack or a long-arm weapon.

It’s also designed to operate in the rugged Arizona desert. “Border control can break anything,” says John

Lawson, CBP acting section chief. “It’s very difficult terrain to deploy technology in, and that’s one of the benefits that we’re anticipating. This system is going to be a lot more rugged than a lot of the previous things we’ve deployed.” Now that the IFT has proved itself worthy, a second installation on the Arizona border is underway, with the ultimate plan of safeguarding the entire Mexico-facing stretch of Arizona’s perimeter, pending congressional approval.

The IFT is only one part of the border patrol’s effort to use technology to enhance security. The Arizona Border Surveillance Technology Plan, which includes the IFT, also uses remote video surveillance—day and night cameras for cluttered urban environments where radar is not as effective—and truck-mounted mobile sensors that can be moved when needed. Drones have been used to provide a bird’s-eye view of vast stretches of border, and in 2012, the agency deployed a military wide-area camera attached to an aerostat, an airship tethered up to 5,000 feet off the ground. Originally used in Afghanistan, these cameras are capable of capturing miles of terrain in a single hi-res image. But officials say that all of the technology, including the IFT system, serves only to support the most valuable assets border patrol has: the agents. “Back in the early days, it was people looking for footprints on the ground,” Lawson says. “We still do that.” Only now, the agents stand a better chance of finding them.



WHAT THESE PEOPLE THINK

Perspectives on border security from the presidential candidates.



DONALD TRUMP

“We need a wall. We have to get a wall... We’ve lost control of our borders. The government has no idea how many illegals there [are]... Nobody has any idea.”



BEN CARSON

“Drones are excellent for surveillance. Along that border we have miles and miles of fences, and, you know, I went there last week and didn’t see any border-patrol people.”



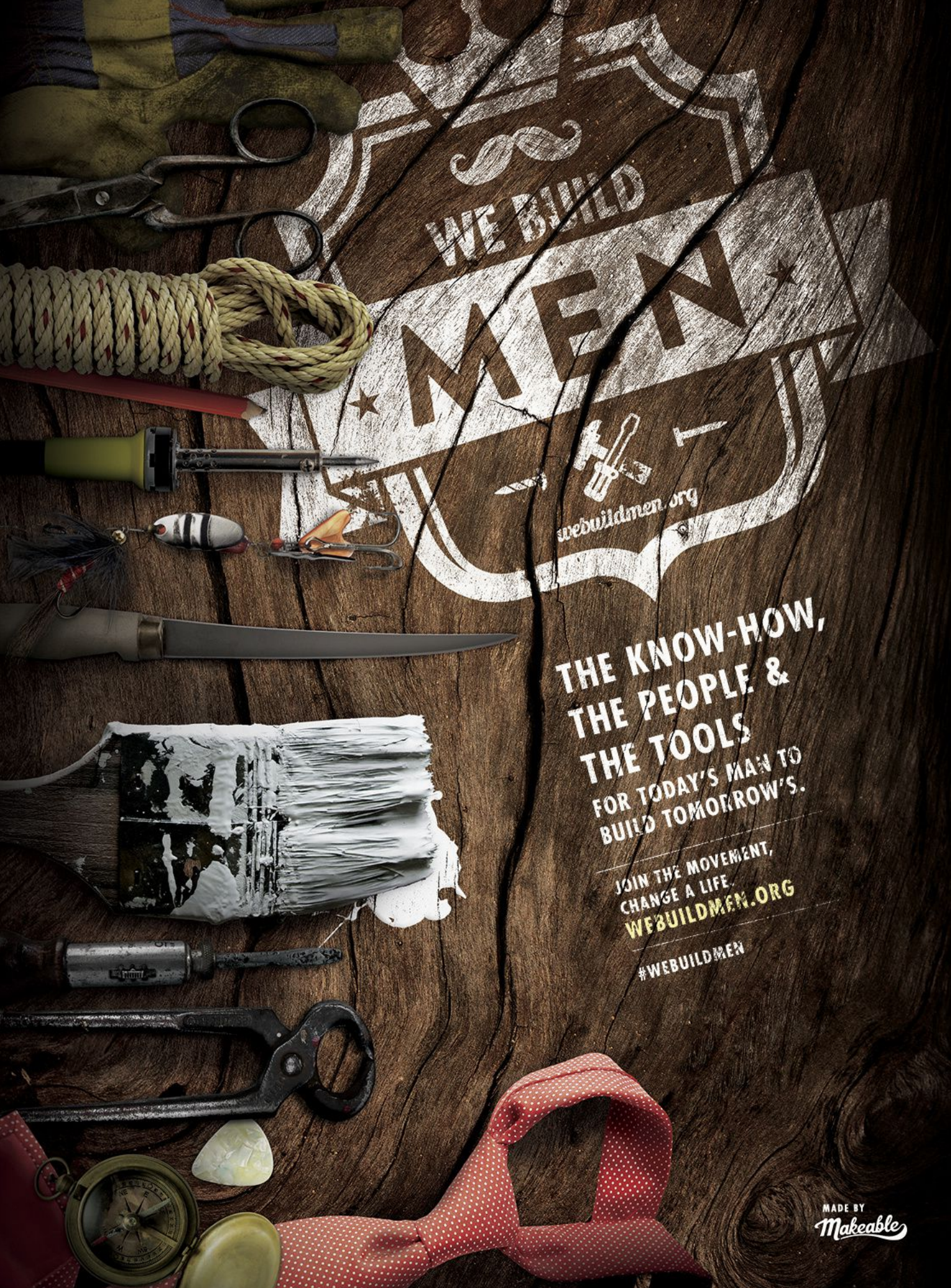
HILLARY CLINTON

“Deploy[ing] more technology and personnel... will give us an opportunity to secure our borders without interfering with... [what] makes living along the border wonderful.”



BERNIE SANDERS

“Let me say what most people already know. Undocumented workers come to the United States to escape economic hardship and political persecution.”



WE BUILD

MEN

webuildmen.org

THE KNOW-HOW,
THE PEOPLE &
THE TOOLS
FOR TODAY'S MAN TO
BUILD TOMORROW'S.

JOIN THE MOVEMENT,
CHANGE A LIFE.
WEBUILDMEN.ORG

#WEBUILDMEN

MADE BY

Makeable



← A Mac running Pro Tools feeds a digitized version of the album to the mixing board at Capitol Records in L.A. Original master tapes for bands including the Beatles and Pink Floyd are in cardboard boxes across the hall.

version he remastered. The remaster is conspicuously clearer, revealing a healthy bottom end that adds rhythmic urgency. In the case of *A Love Supreme*, remastering was essential to even out differences in volume between the original record and the new tracks.

"In the music industry, mastering is referred to as a dark art," says Greg Milner, author of *Perfecting Sound Forever*. "It's a rarefied skill." And as with any skill, there are tools. McMaster has a custom valve-driven analog compressor welded into his mixing board, which he uses to balance the overall volume on a track. He uses equalization, or EQ, to emphasize or reduce certain audio frequencies. Noise reduction, or NR,

surgically removes hums and sibilance.

The process is also an act of preservation. For many albums, the original master tapes were so valuable that engineers made what's called a production master—a second version that could be played constantly for duplication. Overuse often degraded production masters, which is why many compact discs from the 1990s, which used them as a template, have compromised bass and tinny sounds at certain frequencies. So remastering engineers go back to the original tapes. "We used first-generation masters, the sounds the band themselves heard in the studio, for everything on the *In Utero* reissue," says engineer Steve Albini, who worked on the remaster of Nirvana's final album. "The result is a definitive vinyl mold of a cultural artifact."

To make the vinyl edition of *A Love Supreme*, McMaster sends the new first-generation remaster through his mixing console into a huge lathe, which carves the mold for the records. As the needle scores the blank acetate disc, webs of discarded material shoot through a tube into a jar, discarding the junk while preserving the mojo, mistakes and all.

MUSIC

Your New Records

Music labels seem to come out with new remastered versions of classic albums nearly every month. Does the extra engineering matter? Or is it hype?

BY MATT DIEHL

The band kicks in, then abruptly stops. There's silence before the groove begins again. "This kind of false start is something you want to keep," mastering engineer Ron McMaster (yes, that's his real name) explains. "When you hear things like that, it's like you're in the recording session as it's going down." On a vintage mixing console studded with flickering meters, he turns a knob to set the fade-in. The mistake stays.

At Capitol Records in Los Angeles, McMaster is remastering *A Love Supreme*, John Coltrane's genre-defining 1965 jazz album. Verve Music Group, Capitol's co-subsidiary at Universal, released it on CD and in digital format late last year to mark the recording's 50th anniversary. McMaster is working on the vinyl version, which is being released this month. Rather than just digitize the original tapes, he is editing the songs to create a new, sonically immaculate recording of Coltrane's masterpiece.

Some labels use the term "remastered" to resell music indistinguishable from previous recordings. Worse, to work with cheap earbuds, many engineers simply copy an album and make it louder, obscuring nuances. But loving remasters exist, and their practitioners work magic to deliver the musicians' intent. Engineer Robert Vosgien, who works with artists like James Taylor and Elvis Costello, demonstrates by playing Bob Seger's original song "Beautiful Loser" alongside the

FIVE REMASTERED ALBUMS WORTH BUYING



The Beach Boys
Pet Sounds
The most unimprovable version of an unimprovable album, with brighter percussion and harmonies.



Skip James
Hard Time Killin' Floor
Cleaned up so you can hear his picking and those haunting vocals, but never sterilized. The rare proper blues remaster.



Georg Solti
Der Ring des Nibelungen
Quintessential Wagner talent, this 1997 edition was the first to clear background hiss from previous remaster attempts.



Maria Callas
Remastered: The Complete Studio Recordings (1949-1969)
Hearing the first lady of opera shuffle her feet makes this feel like a private recital.



The Smiths
Complete
Guitarist Johnny Marr helped remaster this collection of all eight albums. Superior mixing to previous cash-grab compilations.



WE GO WHERE YOU GO.

On the road to help you save. Now that's Progressive.

PROGRESSIVE[®]

1-800-PROGRESSIVE | [PROGRESSIVE.COM](https://www.progressive.com)

Progressive Casualty Ins. Co. & affiliates. Do not attempt.

WAR

Artists Against ISIS

Can photography protect the historic world from the current one? **BY KEVIN DUPZYK**

As quickly as the Islamic State can destroy ancient relics, researchers are trying to save them. Early last year, the Institute for Digital Archaeology, a partnership between Harvard University and Oxford University, started the Million Image Database project in an effort to collect 3D records of endangered archaeological sites all over the world. The group developed specifications for a stereoscopic camera with the plan to distribute it to people who would have access to sites threatened by conflict, natural disasters, climate change, or lack of resources. When ISIS attacked and partially destroyed millennia-old ruins at Palmyra in Syria last summer, it imposed a new sense of urgency. The IDA began distributing cameras in August, ahead of schedule. It also sent out

three different camera bodies in order to make the photographers harder to identify. The IDA expected to have to recruit photographers, but the desire to help has been so great that all the cameras distributed so far have been to volunteers. At the time of this writing, the IDA was on pace to meet its goal of distributing 5,000 cameras by the end of 2015.

When the IDA receives and processes an image, it puts the image in a database, which will become available to the public this spring. It also plans to print full-size concrete models, some of which will appear in public art shows, while others will serve as replacement antiquities in their original locations. Either way, they'll serve the project's goal, which is to "explore the commonalities in cultural heritage between the East and the West." This is also a good first step to learning to stop blowing each other up.



↑ A stereoscopic photograph of the entrance to the baths at Carthage, Tunisia. It can be seen in 3D with red-and-green glasses.



A 3D rendering of the archway of the ISIS-destroyed Temple of Bel in Palmyra from the Institute for Digital Archaeology's archives. It will be used to create a full-scale reconstruction this spring and could also be printed on a desktop 3D printer.

POPULAR MECHANICS EXPLAINER

How does the U.S. military call in an airstrike?

BY ROBERT VRABEL

Late last year at the Doctors Without Borders hospital in Kunduz, Afghanistan, at least 30 people—including doctors, nurses and patients—died during an American firebombing. Investigators suspect that Taliban fighters may have established offensive positions in and around the hospital and Afghan National Army soldiers—American allies—were allowed to call in help from an American AC-130 gunship. The help they received would have been close air support, one of two types of combat air support the U.S. military commonly uses. The other is deep air support.



(1) **Close Air Support (CAS)** is used by combat units to call in air resources when friendly ground units are involved in direct fire with enemy ground units. Ground units usually radio the aircraft, providing coordinates or directing it with a laser. Most combat units have a JTAC (Joint Terminal Attack Controller) or a FAC (Forward Air Controller) whose job it is to do the calling. The distance between a U.S. unit and the enemy that constitutes "danger close" and authorizes a pilot to fire is different from unit to unit.

(2) **Deep Air Support (DAS)** is usually used when special-operations forces locate nonmoving targets behind enemy lines. These can be buildings, supply routes, or bridges. Forces on the ground light up the target with a SOFLAM (Special Operations Forces Laser Acquisition Marker). On the way down, munitions communicate with the SOFLAM as well as with the aircraft's targeting system, guiding themselves to land as accurately as possible.



**POPULAR
MECHANICS**

WORK/SHOP

A COLLECTION OF PRODUCTS & OFFERS FROM OUR PARTNERS



SOMETIMES IT DOES TAKE A ROCKET SCIENTIST

The only sunglass technology certified by the Space Foundation for UV and blue-light eye protection. Eagle Eyes® Navigator™ Black Sunglasses \$49 + S&P PLUS receive the Navigator™ Gold absolutely FREE!—2 pairs for the price of one!

Call 1 (800) 333-2045 with offer code EEN244-02 or visit www.Stauer.com for more information.



SCIENTIFIC PROOF THAT TRUE LOVE CAN LAST

Our one total carat DiamondAura® Everlasting Anniversary sterling silver ring fuses modern science and old-fashioned romance! Our exclusive lab-created stones burn with more fire than mined diamonds. Everlasting Anniversary Ring — Only \$59 + S&P

Call (800) 333-2045 with offer code EAR236-02 or visit www.Stauer.com for more information.



LEE® MODERN SERIES

New Lee jeans are made with Active Comfort Stretch, so they're super comfortable. And with new cuts and washes, they're our best-looking jeans ever. New Lee jeans, our most comfortable, best-looking jeans ever. Comfort Never Looked So Good.

Visit www.Lee.com for more information.



AMAZING NEW TINY & AFFORDABLE HEARING AID

Fits like no hearing aid before it: nothing behind your ear and nothing in your ear canal. Patented shape uses the natural curves of the ear to fit comfortably, securely without unsightly tubing. Doctor-designed and FDA-registered at 80% less than custom hearing aids. RISK-FREE TRIAL, 100% money back guarantee, FREE batteries for a full year.

Call (800) 873-0698 with promo code CJ89 or visit www.MDHearingAid.com for more information.

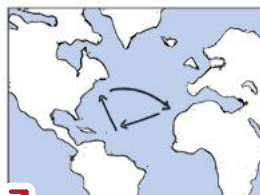
DRINKS

The Boston Rum Party

Thanks to the work of a new generation of distillers, tea won't be the only drink in New England with a notable history. BY FRANCINE MAROUKIAN

The good citizens of colonial Boston drank just as much rum as tea. Rum was an early economic engine there, strategic to Britain's infamous triangular trade route linking sugarcane and slavery (see right). By the mid-1700s, there were more than 60 rum distilleries in Massachusetts, mostly centered on Boston. The molasses came from tropical sugar houses and was initially duty-free and plentiful enough to become a staple of everyday life in iconic dishes such as Boston's baked beans. However, as other countries settled the Caribbean and planted sugarcane, Britain imposed a tax on imports from sources not under the dominion of the Crown. This restriction turned molasses into a crusade and rum making into a revolutionary act.

Today brothers Will (above right) and Dave Willis (left) are reinvigorating Boston's regional rum legacy at Bully Boy, their distillery in the Newmarket district of Roxbury, one of those transitioning industrial areas that still looks like a good place to dump a body. The fourth-generation New Englanders come from boozy stock. Their grandfather's farm, where they grew up, once had an informal speakeasy in the basement, with a vault that held a cache of Cuban rum. "Seeing those bottles growing up, unwittingly and in a roundabout way, set us on the course to founding Bully Boy," Will says. Their four-step process starts with distillery-grade molasses (55 to 65 percent sugar) in 275-gallon plastic totes, each weighing about 3,200 pounds and delivered from Louisiana. "It's a cheap source of sugar with lots of flavor and tons of aromatics," Will says. "The challenge is distilling without losing any of those foundational aspects." Here's how they do it.



Traders used proceeds from the sale of slaves in the Caribbean to buy sugar, which they sold in New England to buy rum, which they traded or sold in Africa for more slaves.

STEP 1 THE MIXING POT

Forty-five gallons of molasses are added to 150 gallons of water and 8 ounces of powdered yeast to create the wash. Because water plays a large part in the final flavor, quality is critical. Luckily Boston has some of the best tap water in the country, with complex minerality and great taste. All Bully Boy does is carbon-filter it to remove particulates and impurities.

STEP 2 FERMENTATION

The wash is pumped into a stainless-steel tank in which the yeast first consumes oxygen, bubbling wildly like a sixth-grade science project, and then sugar, giving off alcohol as a by-product.

STEP 3 DISTILLATION

The fermented mixture is pumped into the distilling pot, a copper vessel with a stainless-steel jacket wrapped around its bottom half. Steam is pumped into the jacket to evaporate the alcohol. Because different alcohols boil at different temperatures, the speed at which the steam is released determines the burn-off rate. Each stage of burn-off has a name: the head, the heart, and the tail. The steam pushes off the vapor, which is released into the still columns where it collects and condenses. "The art of distillation, and the palate for each distiller, is the manner in which heads, hearts, and tails are combined," Dave says. "We take more at the start, but some distillers prefer the back-end earthy funk of tails."

STEP 4 FINISHING The spirits are diluted with water to bring them to bottle strength, macerated with different elements to introduce new flavors, or rested in barrels to add color and dimension.



THREE
GREAT NEW
ENGLAND
RUMS

1 Bully Boy Boston Rum 80 PROOF

This dark, savory rum is double-rested, first in used American whiskey barrels at No. 3 char, letting the subtle sugarcane flavor shine through, and then in used red-wine barrels to add color and a little fruitiness.

2 Twenty Boat Spiced Rum 95 PROOF

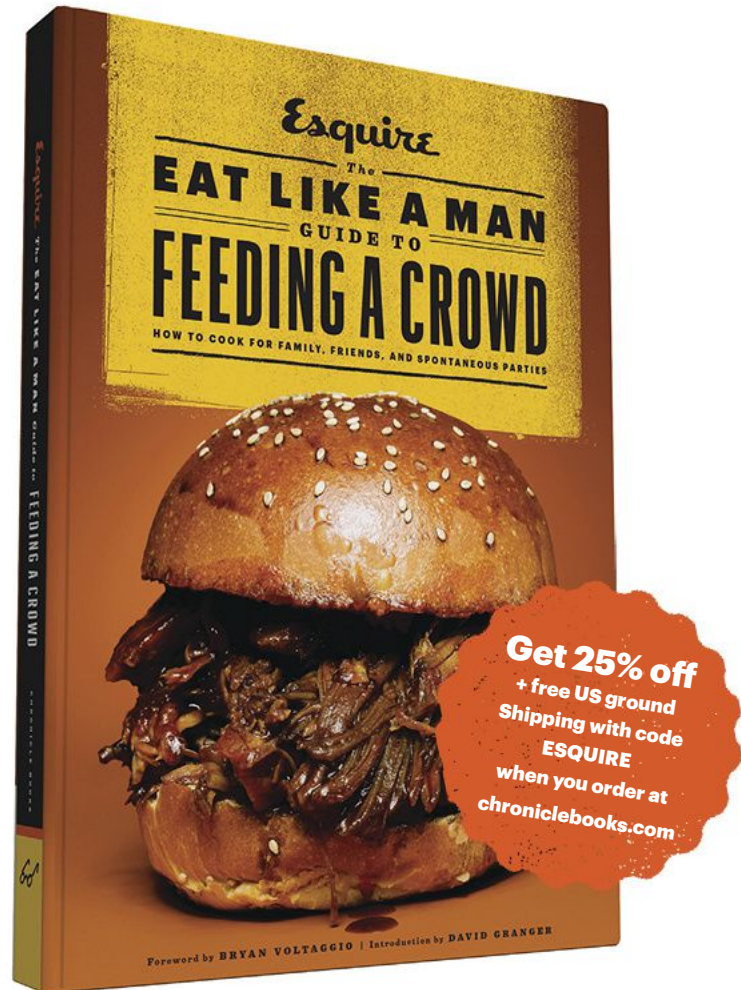
Twice distilled by Cape Cod's Truro Vineyards, Twenty Boat starts with peppery spices like cardamom and allspice and finishes with a Boston-appropriate undertone of tea.

3 Rusticator Rum 90 PROOF

From Bartlett Spirits of Maine Distillery, Rusticator is aged in oak barrels and has flavors of honey, a soft toffee sweetness, and a whiff of smoke.

The only cookbook you'll ever need when the party is at your place!

The ultimate resource for guys who want to host big crowds and need the scaled-up recipes, logistical advice, and mojo to pull it off. Whether they're cooking breakfast for a houseful of weekend guests, producing an apic spread for the playoffs, or planning a backyard BBQ. Includes more than 80 recipes, with favorites from chefs such as Tom Lolicchio, Mario Batali, and Bryan Voltaggio.



CHRONICLEBOOKS.COM

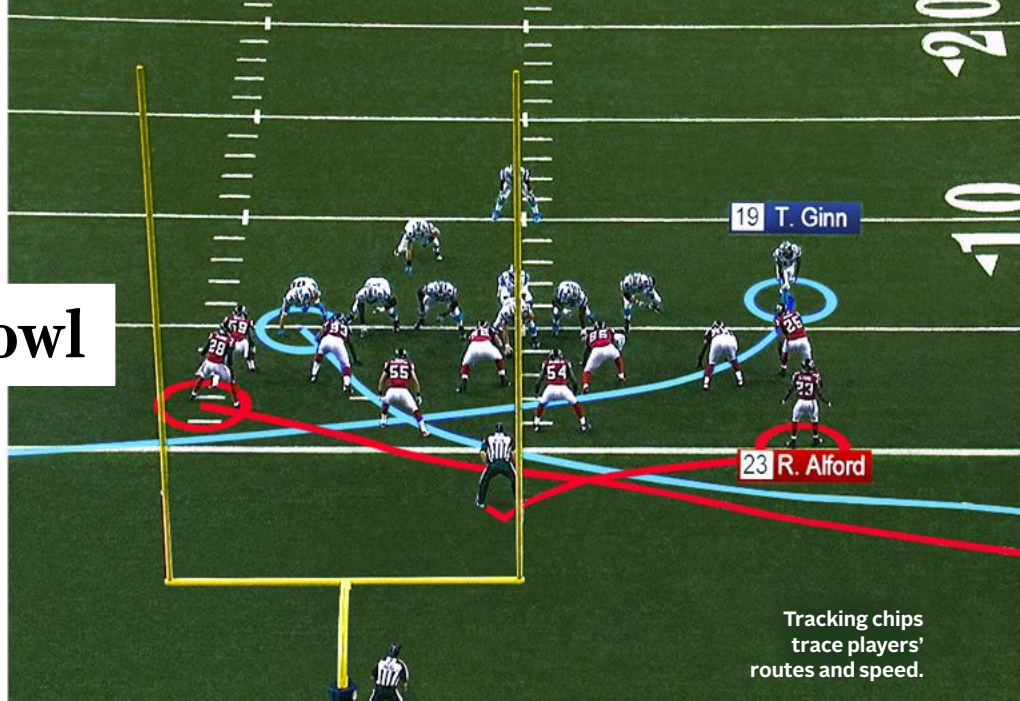
Esquire

FOOTBALL

The Future Bowl

Super Bowl 50 is being held in one of the most technologically advanced stadiums in the country, with cutting-edge security and a new app for fans. Even the ads are getting an upgrade.

BY LARA SOROKANICH



Tracking chips trace players' routes and speed.

1 Super Bowl 50 host Levi's Stadium, in Silicon Valley, provides Wi-Fi to 70,000 fans using 1,200 antennas and 400 miles of cabling. The first LEED Gold certified stadium in the NFL has three solar-paneled pedestrian bridges and a solar-paneled roof deck, which provide enough power to offset what's used in the game.

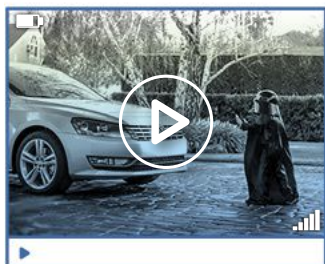


2 This year, the NFL mobile app is expanding to include features from Levi's Stadium's own, more advanced app. Fans will be able to access instant highlights for every play from four angles. The app will also let fans order food for pickup or delivery from their seats.

3 This will also be the first Super Bowl to take full advantage of Zebra tracking chips, a technology first tested in 2014 and officially instated in all NFL teams in 2015. The GPS chips, which are about the size of a quarter and are embedded in players' shoulder pads, give real-time statistics and locations of players, including how far and how fast they've run during a given play. The information the chips provide will be translated into more accurate and immediate stats for broadcast commentary and also displayed throughout the stadium during the game.

4 Given the Super Bowl's high security-threat status (level one, according to the Department of Homeland Security), the Santa Clara Police Department has established a shared network between the stadium and the Santa Clara Valley Transportation Authority. Video cameras from existing infrastructure, plus new mobile cameras, a map of all the Santa Clara Valley trains and buses, and searches of social media, among other data, will create a real-time picture of everyone traveling to, from, within, and around the event. In high definition.

How Live-Streamed Ads Will Change Everything



► *In deference to the steadily increasing number of people who watch the game on a computer, NBC now requires all Super Bowl ads to be available online and on TV simultaneously. Advertising agency Ogilvy & Mather's editorial director **Jeremy Katz** explains what that means for viewers.*

For some of us, the Super Bowl has transformed into a short

film festival interrupted by a mediocre game, which makes this news very big. First of all, it will be another way for brands to be part of the digital experience. What a win for both advertiser and viewer, right?

That depends. Brands haven't exactly covered themselves in glory when it comes to understanding the Internet. For every grand slam, like Oreo's

impromptu "You can still dunk in the dark" tweet during the 2013 blackout, there's a stadium full of ineptitude. Smart brands will not see this as just another platform to push their commercials. They'll extend your experience with them, nudging you to engage in a way that offers some kind of value. There may be ads where you can change the ending, ads

that enable you to shop directly off the screen, ads that offer free stuff if you participate. Cool. The flip side: Brands with less creativity (but just as much money) will use the increased immediacy to try to interrupt your overall entertainment vibe with needy shouts for attention. More tweets. More hashtags. That was the norm online before, but now it's just annoying.



**Just because you don't see it,
doesn't mean it isn't there.**

Introducing the newly redesigned Volkswagen Passat with Blind Spot Monitor, one of seven available Driver Assistance features.* Passat. Where family happens.



DISASSEMBLY REPORT

JACKHAMMER

MODEL: DEWALT D25980

PRODUCED: PERUGIA, ITALY

TIME TO DISASSEMBLE:

3 HOURS,
40 MINUTES,
29 SECONDS

NUMBER OF PARTS:

224

NOTES: The first U.S. patent for a “percussion rock drill” was awarded to Joseph J. Couch in 1849. His drill, invented for mining, was powered by a steam engine and repeatedly threw a bit, javelin-style, at rocks. In 1895, a patent for a tool most of us would recognize as a jackhammer was awarded to Charles Brady King (incidentally, also the first guy to build a car in Detroit). Like many pavement breakers in use today, it was pneumatic, tethered to a hose that delivered compressed air. In comparison, other modern pavement breakers, like the DeWalt D25980 pictured here, are downright refined: electric, relatively lightweight, and compressor-free. So the next time the noise of a jackhammer brutally wakes you at 6:30 on a Saturday morning, think: It could be much worse.



STARTING THE MACHINE

The jackhammerer holds the handles like the handles of a bike. The **left handle (1)** is hollow. The **right handle (23)** is filled with electronics, including the **paddle (22)** that turns the unit on and off. Squeezing the paddle triggers an electrical switch that starts the 15-amp **brushed electric motor (2)**. The motor is electronically governed to get up to speed slowly, so the jackhammer doesn't bounce off the ground before it finds purchase. After a few low-energy impacts gouge the surface, intensity ramps up and the tool digs in. At full speed, the pavement breaker delivers 900 blows per minute.

BREAKING CONCRETE

A pavement breaker is a sealed column of air with a piston engine on top and a chisel on the bottom. A drivetrain of reciprocating parts contained in the **front housing (20)**, which bolts below the **motor housing (24)**, does the work. The **piston**

(9), connected to the motor via the **crankshaft (21)**, points straight down and drives a series of thumping devices that ultimately reach the bit. To reduce wear, a column of air separates the piston from the first of these pieces, a heavy weight of hardened high-carbon steel called the **ram (8)**. The piston pushes air through the column to move the ram, which in turn hits the **beat piece (19)**. A green rubber **bumper (17)** that dampens impact buffers the beat piece. A white **felt seal (16)** keeps in lubrication and three **O-rings (6, 18)** keep dust out, so it moves smoothly.

Finally, the beat piece slams into the **bit (15)**, which is secured by the **holder assembly (11)**. Bits come with two types of attachment mechanisms: ring or notch. To accept the former, the **retainer (10)** flips down to grab the bit under the lip of the ring. To accept the latter, it flips up to squeeze the notch. There are also lots of different tips. Of the three pictured here, the **bull, or moil-point**

HOW TO JACKHAMMER BY HAND

(1)

Find an edge or crack in the concrete with room to wedge a pry bar under the slab.

(2)

Using the bar as a lever, lift the slab. Jam a big rock or piece of lumber underneath to prop it up.

(3)

If you haven't yet, put on safety goggles.

(4)

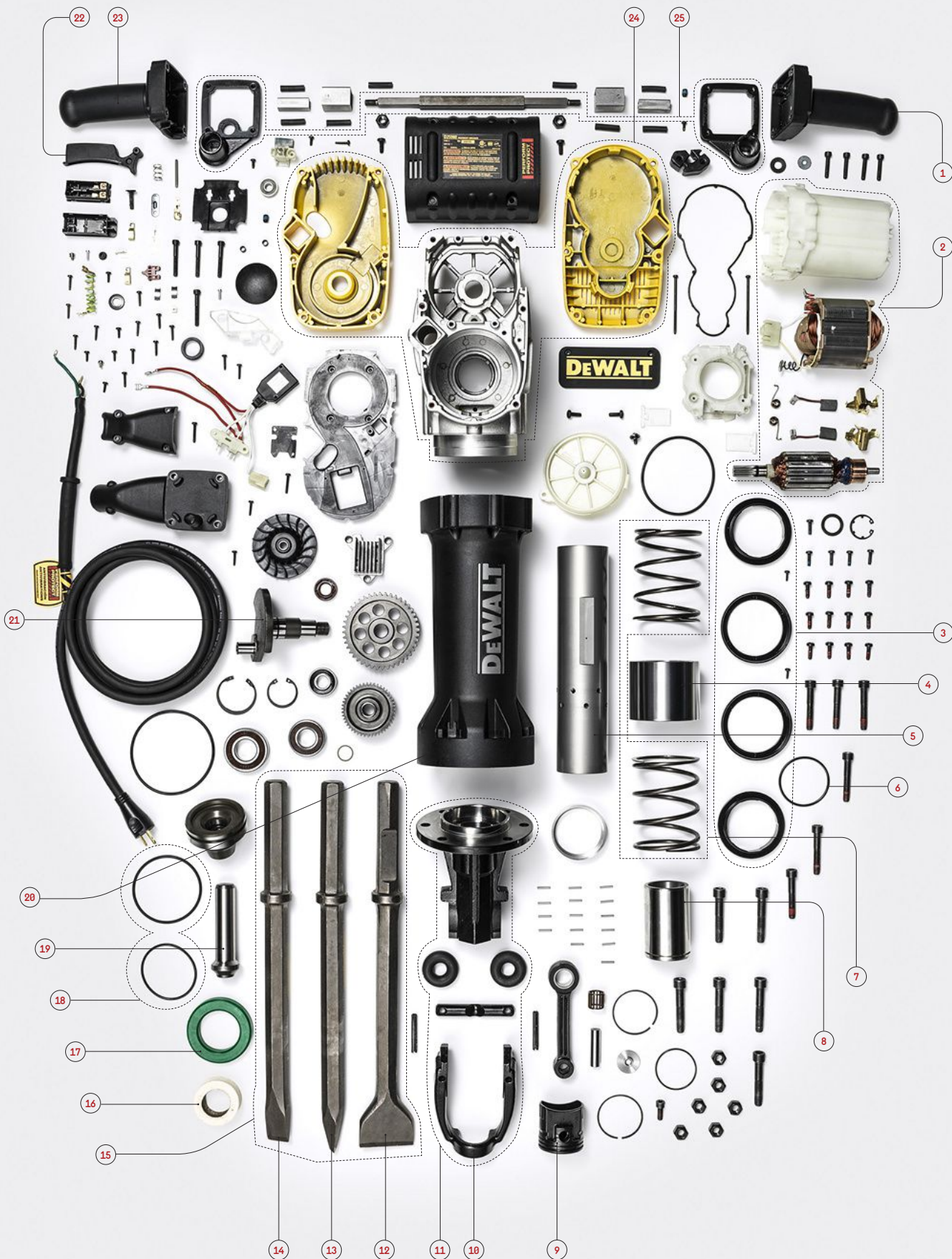
Smash the propped-up slab with a sledgehammer.

chisel (13), is for general demolition, while the 1-inch **cold chisel (14)** and the 3-inch **scaling chisel (12)** are for finer work, like removing only one panel from a sidewalk.

PROTECTING THE OPERATOR

Essentially, what a pavement breaker does is repeatedly slam a chisel into the ground, which should not be pleasant for the guy holding the other end. To manage vibration, the handles are attached to the tool with a **plate assembly (25)** consisting of two rubber brackets for padding and a long metal bolt. The bolt passes through the body of the tool so that the handles can float independently of it. Complementing this is a counterweight system: As the beat piece drives the bit into the ground, **coil springs (7)** pull a die-cast steel **counterweight (4)** up the outside of an aluminum **cylinder (5)** that surrounds the drivetrain. **Guides (3)** stabilize the counterweight, and no one breaks any bones.

—Kevin Dupzyk



GREAT UNKNOWN

BIG QUESTIONS.
ANSWERS YOU CAN'T FIND
ON THE INTERNET.

Q



How do you know if a car mechanic is on the level or scamming you? Are there telltale signs?

A IF A MECHANIC suggests replacing more than four wheels, two axles, or one steering wheel, you may wish to investigate further. Repairs that propose to employ “an X-Acto wrench,” “liquid staples,” or a microwave oven should be declined. Also, note: No current production vehicle requires dilithium crystals to function correctly.

Actually, despite the old stereotype, the kind of mechanics, or to use the preferred nomenclature, “technicians,” who run up your bill aren’t trying to scam you. They’re just numskulls. “There’s a fair amount of incompetence, particularly in smaller shops where people are trying to work on newer cars that they don’t understand,” says AAA’s manager of technical services Michael Calkins. “People tend to throw parts at problems, and parts for modern cars are very expensive.”

Modern cars are also very complex. Nowadays, every vehicle relies upon a sophisticated onboard diagnostic system, known as OBD-II, which means technicians need to be as versed in computers as they are in carburetors, and often must follow time-consuming protocols to properly assess and repair ailing vehicles. Experts suggest seeking out mechanics with certifications from an organization called ASE (that’s Automotive Service Excellence), which subjects would-be wrench wranglers to exams and requires evidence of practical experience.

That said, some technicians earn commissions, which may provide an incentive if not to

outright lie, then at least to up-sell drivers on work that may not be wholly necessary. An oil-change customer may be sweet-talked (or, if the guy’s a real shark, frightened) into a brake job a few thousand miles early, for instance. The best defense against this, say both ASE and AAA, is to RTFM. Your car’s owner’s manual will lay out the appropriate maintenance schedule. Stick closely to this and you shouldn’t be led too far astray. One final caution: The only thing an honest technician will ever suggest you “flush” is your toilet.



When will wires no longer connect or charge our electronics?

Brother, if you’re still connecting electronic devices to each other with wires, you might want to set down your club, step out of the cave, and take a good look around. It’s pretty rare that a wired connection is required to transmit data, as anyone with even a cordless phone can tell you. There are some exceptions, but, in general, that problem has been dropped into the “solved” file we keep on our cloud server.

If you’re talking about charging batteries without cumbersome cabling, well, now you’re onto something. Current research and development promises one day to allow us to charge our phones and other devices wirelessly. The dream is that we’ll be able to move through our lives wholly untethered—just passing through public (or in-home) “charging zones” would top us off, using elec-

Do you have unusual questions about how things work and why stuff happens? This is the place to ask them. Don’t be afraid. Nobody will laugh at you here. Email greatunknowns@popularmechanics.com. Questions will be selected based on quality or at our whim.

tromagnetic induction, in which magnetic fields generate electricity.

None of this is going to happen next week. The technology needs to improve, and manufacturers need to agree on a single standard. The two competing technologies at present are Qi inductive charging, promulgated by a consortium known as the WPC, and Rezence wireless power transfer, backed by a group using the inscrutable acronym A4WP/PMA.

Qi, favored by the likes of Nokia, Microsoft, and Sony, uses a transmitter/receiver model to transfer power and can do so over a 45-mm distance. It can also penetrate, say, a tabletop, so you could mount the receiver under your desk, for instance. Rezence, which counts AT&T and Intel among its adherents, works similarly, but its magnetic induction coils operate at a different frequency, rendering the two approaches incompatible.



Has anyone ever had sex in space?

Astronauts may drink Tang, but odds are they’re not getting any. Over the past 54 years, more than 500 men and women have traveled into space, including a married couple. Human nature being the filthy, dirty thing that it is, it may be hard to believe that everybody up there has been, you know, “just friends.” But both American and Russian space authorities insist that’s the case, and there’s reason to believe them.

NASA, an unfailingly high-minded organization, refused to entertain our puerile inquiries this time around, but we did reach Jim Logan, a former NASA flight surgeon and cofounder of the Space Enterprise Institute, who had some thoughts on the matter. Firstly, sex in space would be challenging and inconvenient. A zero-gravity environment would make the act itself a frustrating physics lesson, as every action’s proverbial equal and opposite reaction would tend to separate the participants. Assume, though, that our theoretical lovebirds work out an elaborate (and ever-so-erotic!) system of straps, slings, and pulleys. They’d still be floating around, bashing their heads against walls, spilling the freeze-dried ice cream, knocking into warp-drive levers, etc. Talk about unsafe sex.

Moreover, some have suggested that lowered blood pressure due to a lack of gravity might prevent men (especially), but also women, from becoming physically aroused, though Logan discounts that. “Humans,” he says, “can get aroused pretty much anywhere.”

Consumer Cellular®



PICTURED ABOVE:
Motorola Moto G LTE, Huawei Vision 3 LTE,
Doro PhoneEasy® 626

FANS ALL OVER THE COUNTRY ARE SAVING.



SWITCH TO THE HIGHEST RATED MOBILE CARRIER TODAY—100% RISK-FREE[†]

- ✓ Plans start at just \$10 a month
- ✓ Reliable Nationwide Network
- ✓ No Contracts
- ✓ Free Activation—a \$35 Value
- ✓ Competitive plans for one, two or families
- ✓ 100% U.S. Based Customer Service

AARP
Real Possibilities

Member **Advantages**

AARP Members, ask about your special benefits when starting service.

CALL FOR MORE INFORMATION
(888) 927-8433

VISIT US ONLINE AT
ConsumerCellular.com/PopularMechanics



ALSO AVAILABLE AT
TARGET **sears**®

© 2016 Consumer Cellular, Inc. New service activation on approved credit. Cellular service is not available in all areas and is subject to system limitations. Terms and Conditions subject to change. [†]Based on interpretation of Nielsen's Mobile Insights survey data, which uses respondents' self-reported rating (1 to 10 scale) of overall satisfaction with their carrier from a national survey of approximately 90,000 U.S. mobile phone users during Q3 '15. If you're not satisfied within the first 30 days, 300 minutes, 300 texts or 300MB of data, whichever comes first, cancel and pay nothing.

AARP member benefits are provided by third parties, not by AARP or its affiliates. Providers pay a royalty fee to AARP for the use of its intellectual property. These fees are used for the general purposes of AARP. Some provider offers are subject to change and may have restrictions. Please contact the provider directly for details.

Don't Get Burned

Dangerous and potentially deadly counterfeit products, from extension cords to cell phones, are purchased every day.

Take this extension cord, for instance. If you bought it "on the cheap," you could be... well, playing with fire. Fake products are made without safety standards, and they put you and your family at risk. Stick with reputable products from trusted sources and you won't get burned.

**Counterfeits Hurt.
You Have the Power to Stop Them.**

Protect yourself from counterfeit products.
Visit **NCPC.ORG/GETREAL**



BJA
Bureau of Justice Assistance
U.S. Department of Justice



Scan this code to view more



©2011 National Crime Prevention Council

KNOW-HOW

BAND SAWS | ICE FISHING | SHOP NOTES

How to Build a House

The best way to teach construction skills to kids is to actually let them construct something. Not just a coatrack or a cute birdhouse. A real house.

BY MATTHEW JOHNSON
Forest Grove High School, class of 2016



The author, circled, and the Viking House team atop their 2014–2015 construction. Teacher Chris Higginbotham is on the far right.

Every fall since 1974 at Forest Grove High School in Forest Grove, Oregon, the students in the Viking House project have begun the school year with nothing more than a plot of land. By June they have a completed house. The program was started by Birt Hansen and is now run by a local contractor turned teacher, Chris Higginbotham. In four decades, it's remained completely self-sustaining: The profits from one house pay for the materials for the next. The labor, of course, is free. And grateful. One student shares his experience.



I DON'T COME from a particularly handy family—my parents have no trade skills whatsoever—but I have always been curious about building things. When my two older brothers went through the Viking House program, I saw how much they enjoyed it and how much they learned, and I decided I wanted to do it, too. After enrolling in 2014, I fell in love with working with my hands. So much that I am one of only two returning students in this year's program.

Viking House is probably the most real and applicable class you can take in high school. You have to complete some prerequisites, including woodworking and basic construction classes, before you can join, but after that you get to start working on a house. I've learned a lot and gotten much more familiar with tools in general. Before I started the class my nail-driving skills were not good; now they're second only to the instructors'. Some tools, like the circular saw, were a little scary to be around at first. Those things are dangerous. Once I learned how to control one and to respect its power it got a lot more comfortable. Viking House has also taught me how to interact with other people better. As a returning student, I've had the opportunity to teach my



➔ **HOW TO BUILD A HOUSE (continued)**

classmates a few skills. Sometimes the way I'm explaining something just won't get through, and instead of getting frustrated I try a different approach. I've become a better teacher. I understand other people better and work better with them. I even got a job out of it. Last summer I worked on a real construction crew run by two Viking House alumni.

The woodshop is my favorite place to be in school. Whenever I have free time, that's where I am. We pre-cut a lot of things, so there's always something to work on. We pre-cut outlookers (the wooden joists that form the eaves of the house), plywood, and window frames. It saves us a ton of time out on the job. All of these things are premade and ready to go.

Every week during the school year we spend between six and ten hours per week on the site, depending on our class schedules. We also have "work parties" on holidays and some weekends when we work on the house. I don't consider it work, though. It's fun. Last year I put in 58 extra hours outside of school.

At the beginning of each class we all check in at the woodshop, pick up our class-issued tool bags—filled with a framing hammer, speed square, 25-foot tape, chalk line, utility knife, carpenter's pencil, hard hat, safety glasses,

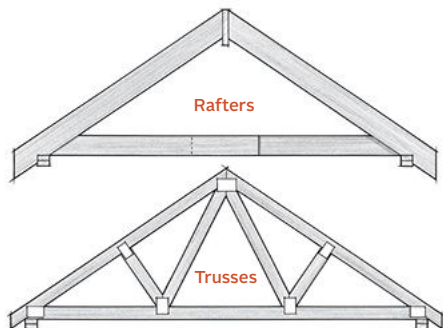
and gloves—and take a bus to the job site. We hire a team to dig out the foundation and get professional help for the plumbing, electrical work, and drywall, but everything else we do ourselves. We'll frame and raise walls [A], add windows, and even put up the roof supports, or trusses (see below).

The day we put trusses on the house [B] is the best day of the year. We take a field trip out to the house in the morning, where our teacher, Mr. Higginbotham, provides coffee and breakfast. The trusses arrive premade on a truck. Two professionals and a few expert volunteers help us put them up [C]. By the end of the day, you feel like a professional yourself. You've put in

a full day of work on a construction site—and it's work you can see. With the trusses up, the site really looks like a house.

In 40 years, Viking House has never missed a deadline. The house always goes on the market, and it always sells. We use that money to pay for the next house. But that's not what's really important. Once you've helped build a house you develop a kind of ownership of it. It is a little sense of pride, especially when people go through the house and they don't know it's built by high schoolers. They're so amazed that you usually have to tell them a few times.

—As told to Cameron Johnson



**A SKILL YOU CAN
LEARN FROM VIKING HOUSE
BUILD TRUSSES**

There are two standard ways to build your roof: rafters and trusses. Rafters allow for more attic space and customization, but if you're not looking for a place to store that trunk full of high school memories or to feature breathtaking cathedral ceilings in your home, opt for trusses instead. Rafters need to be constructed on-site, which takes a lot of time. Trusses arrive preassembled and can be installed in as little as one day. Less time building means more money saved.



Let's
Go
Places

PLAY NOW



Learn more at toyota.com/tacoma

Professional stuntperson. Do not attempt. Prototype shown with options. Production model may vary. BMX riders may vary. ©2015 Toyota Motor Sales, U.S.A., Inc.

THE ALL-NEW
TACOMA

TOOL TEST

THE PROVING GROUND FOR EVERYTHING

Cordless Band Saws

Over several days of testing we cut three different types of pipe: PVC, thick-wall aluminum, and copper. Then we moved on to angle iron, rebar, cold-rolled steel, and conduit. The best tool for you depends mostly on where you'll be using it—and how quickly your arms get tired.

—RICHARD ROMANSKI



★★★★★

Bosch BSH180-01 \$400

BATTERY: 18-v Li-ion, 4 Ah
CUT CAPACITY (DIA.): 2½ in.

LIKES: The smallest and lightest saw exhibits the best fit and finish of the three midsize machines. Its well-positioned side handle is useful for overhead cuts. It helps make the saw less tiring to use but does not interfere with your view of the cut line. A good option for electricians and plumbers.

DISLIKES: Tight quarters in the blade compartment make changing the blade difficult.

WEIGHT
7.7 lb



★★★★★

DeWalt DCS371P1 \$330

BATTERY: 20-v Li-ion, 5 Ah
CUT CAPACITY (DIA.): 2½ in.

LIKES: With a coarse blade running at 570 feet per minute, the DeWalt dominates softer materials including aluminum and copper and was the fastest cutter we tested. And its owner's manual is the most thorough of the five options. A huge help in setup.

DISLIKES: The angle of the LED light casts a shadow behind the blade, making it difficult to view the cut line in some circumstances.

WEIGHT
8 lb



★★★★★

Makita XBP02 \$499

BATTERY: 18-v Li-ion, 5 Ah
CUT CAPACITY (DIA.): 4¾ in.

LIKES: A bruiser of a saw. The six speed options make it easy to adapt to the hardness of the material. This precise speed control means the saw is a good fit for both shop fabricators who work mostly with steel and contractors who primarily cut copper and plastic pipe.

DISLIKES: Adjusting the material guide is a fussy process requiring an Allen wrench. It should be tool-free and fast.

WEIGHT
13.3 lb

KNOW-HOW

★★★★★

Milwaukee
2729-22 \$479

BATTERY: 18-v Li-ion, 4 Ah

CUT CAPACITY (DIA.): 5 in.

LIKES: A combination of massive capacity and power. At 380 feet per minute, the adjustable speed doesn't get as high as some of the other saws, but it's still plenty fast. We appreciated the three-position material guide, which adjusts without tools, permitting better control of the saw and making the Milwaukee the test's most accurate saw.

DISLIKES: The weight can make it tiring to use in overhead cuts.

WEIGHT
15 lb



HOW TO HOLD A BAND SAW

Light saws can be held with one hand. Otherwise, your dominant hand goes on the trigger handle, with the other hand on the front grip for support.



★★★★☆

Stout STX-250C \$473

BATTERY: 18-v NiCd, 2 Ah

CUT CAPACITY (DIA.): 2½ in.

LIKES: The Stout was the original cordless band saw, and it's still a pretty great machine. It's light enough for one-hand use. Plus it's the only saw that comes with a stand, which conveniently lets it serve as a mini-cutting station.

DISLIKES: The design is starting to feel a bit dated. It could use more comfortable handles, better grip surfaces, and a work light.

WEIGHT
9 lb

Cold-Weather Work Gloves

Because fingers tend to function better when you can feel them.

01 / Mechanix Wear FastFit Insulated \$20

Thin and comfortable gloves that provide some warmth and excellent mobility. Great for hand tools or driving that truck you still keep despite the busted heater. Works on touchscreens.

02 / Carhartt A513 Insulated Leather Work Gloves \$24

Moderate dexterity and warmth with classic styling. The Thinsulate

lining made these the softest gloves we tried. Like slipping your hand into silk. Very manly silk.

03 / DeWalt DPG750 \$35

Midweight, durable, and puncture-resistant, thanks to PVC-reinforced palms. The tight fit at the trigger finger means you'll still be able to operate a circular saw.

04 / Duluth Trading Winter Work Gloves \$40

Lightweight but warm,

with an almost sandpaper finish on the palm that provided the best grip. A little too much space in the fingertips makes picking up screws difficult.

05 / Mechanix Wear Polar Pro \$65

Thermoplastic-rubber pads on the fingers and knuckle padding protect against impacts. Surprisingly agile for such tough gloves. Perfect for any outdoor demo project.

TOOL TEST

THE PROVING GROUND FOR EVERYTHING YOU NEED

KNOW-HOW



Flashlights

Five lights to get you through almost any situation. All of them are better options than the one on your phone.

★★★★★

**01 / Maglite
ML300LX \$84**

LUMENS: 625

This battery-operated American-made light fuses classic Maglite design with tactical features like a brilliant LED bulb, a crisp electronic switch, and an aggressively textured barrel. Its workmanship is world class.

★★★★☆

**02 / Dorcy Power
Bank Lantern \$70**

LUMENS: 700

The most versatile lighting tool in this test can be used as an extremely bright LED flashlight, a lantern, or an emergency flasher. And it's rechargeable. The strobe and the lantern are on opposite sides of the power bank, allowing you to operate each independently or together.

★★★★☆

**03 / Pelican Nemo
2010 \$60**

LUMENS: 109

Add batteries and this LED light is ready to go anywhere, whether you take it on a walk through a hurricane or a swim in the lake. It's rated for submersion to 328 feet. To turn it on and off, just twist the glow-in-the-dark lens shroud.

★★★★☆

**04 / Fenix
UC35 \$90**

LUMENS: 960

It's amazing that something the size of a cigar could be so bright. This rechargeable light can be tossed in your toolbox or mounted on your carbine. It has a knurled body and a pocket clip. The five levels of brightness include a defensive strobe mode to, believe it or not, shine into the eyes of an assailant.

★★★★☆

**05 / Pelican 1810
Keychain Light \$13**

LUMENS: 16

A beautifully made water-resistant light that runs eight hours and 45 minutes on four coin cells. Worth adding to any set of keys.

How a Chicago Doctor Shook Up the Hearing Aid Industry with his Newest Invention

New nearly invisible digital hearing aid breaks price barrier in affordability

Reported by J. Page

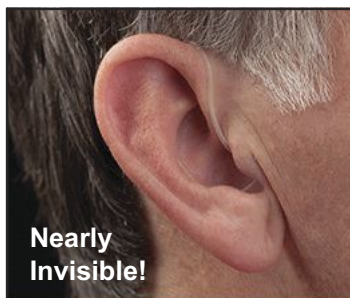
Chicago: Board-certified Ear, Nose, and Throat physician Dr. S. Cherukuri has done it once again with his newest invention of a medical-grade, ALL-DIGITAL, affordable hearing aid.

This new digital hearing aid is packed with all the features of \$3,500 competitors at a mere fraction of the cost. **Now, most people with hearing loss are able to enjoy crystal clear, natural sound—in a crowd, on the phone, in the wind—without suffering through “whistling” and annoying background noise.**

Digital Hearing Aid Outperforms Expensive Competitors

This sleek, fully programmed, light-weight, hearing aid is the outgrowth of the digital revolution that is changing our world. While demand for “all things digital” caused most prices to plunge (consider DVD players and computers, which originally sold for thousands of dollars and today can be purchased for less), the cost of a digital medical-grade hearing aid remains out of reach.

Dr. Cherukuri knew that many of his patients would benefit but couldn't afford the expense for these new digital hearing aids. Generally they are *not* covered by Medicare and most private health insurance plans.



Nearly Invisible!

SAME FEATURES AS EXPENSIVE HEARING AID COMPETITORS

- ✓ Mini Behind-the-Ear hearing aid with thin tubing for a nearly invisible profile
- ✓ Advanced Noise Reduction to make speech clearer
- ✓ Feedback Cancellation eliminates whistling
- ✓ Wide Dynamic Range Compression makes soft sounds audible and loud sounds comfortable
- ✓ Telecoil setting for use with compatible phones, and looped environments like churches
- ✓ 3 Programs and Volume Dial accommodate most common types of hearing loss even in challenging listening environments

The doctor evaluated the high-priced digital hearing aids on the market, broke them down to their base components, and then created his own affordable version — called the MDHearingAid *AIR* for its virtually invisible, lightweight appearance.

Affordable Digital Technology

Using advanced digital technology, the MDHearingAid *AIR* automatically adjusts to your listening environment — prioritizing speech and de-emphasizing background noise. Experience all of the sounds you've been missing at a price you can afford. This doctor designed and approved hearing aid comes with a full year's supply of long-life batteries. It delivers crisp, clear sound all day long and the soft flexible ear domes are so comfortable you won't realize you're wearing them.

Try it Yourself at Home 45-Day Risk-Free Trial

Of course, hearing is believing and we invite you to try it for yourself with our RISK-FREE 45-Day home trial. If you are not completely satisfied, simply return it within that time period for a full refund of your purchase price.

MDHearingAid® >>> AIR

**For the Lowest Price plus
FREE Shipping Call Today**

800-239-7637

**Phone Lines Open
24 Hours EVERY DAY**

**Use Offer Code CG25 to get
FREE Batteries for a Full Year!**

www.MDHearingAid.com



Can a hearing aid delay or prevent dementia?

A study by Johns Hopkins and the National Institute on Aging suggests older individuals with hearing loss are significantly more likely to develop dementia over time than those who retain their hearing. They suggest that an intervention—such as a hearing aid—could delay or prevent dementia by improving hearing!

“Satisfied Buyers Agree, AIR is the Best Digital Value!”

“I am hearing things I didn't know I was missing. Really amazing. I'm wearing them all the time” —Linda I., Indiana

“Almost work too well. I am a teacher and hearing much better now” —Lillian B., California

“I have used many expensive hearing aids, some over \$5,000. The AIRs have greatly improved my enjoyment of life” —Som Y., Michigan

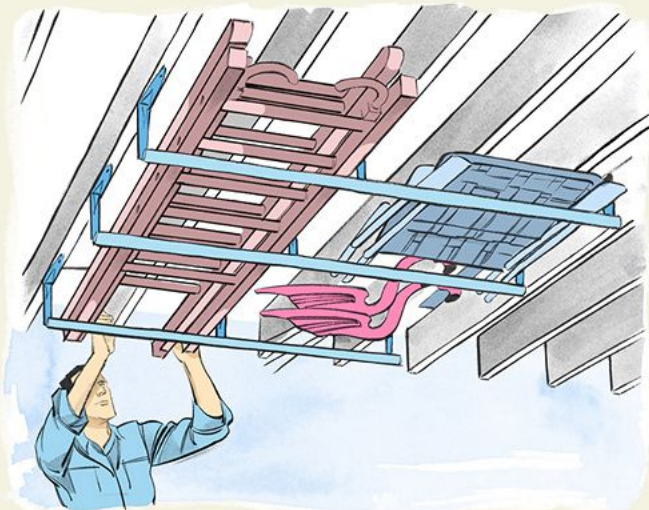
“I would definitely recommend them to my patients with hearing loss” —Amy S., Audiologist, Indiana



SHOP NOTES

EASY WAYS TO DO HARD THINGS

KNOW-HOW



Easy Overhead Storage for the Garage

FREE UP SPACE in the garage by moving lightweight but obtrusive items like ladders and lawn chairs to a ceiling storage system, which is easy to make. Get a few pairs of L-shaped shelf brackets. Fix them in pairs to ceiling joists at a width sufficient for the ladder, lawn chair, or other item to fit between. Then, using the screw holes intended for shelves, connect the hanging ends with dowels—old broomsticks work great, making it easy to slide items into place.

QUICK CHECKS FOR EXPIRED FOOD



Eggs

Eggshells are porous, so eggs fill with air over time. Dropped in a bowl of cold water, old eggs will float, while fresh eggs sink to the bottom.



Avocado

Remove the stem and examine the flesh underneath. A pleasant green indicates an avocado that is ripe and delicious, while brown or black is as good as compostable.



Baking Powder/Soda

Spoon a little baking powder into hot water, or baking soda into white vinegar. If either fails to provoke bubbling, it should be discarded.

Improve Your Clothes Iron

Some clothes irons leak water, which soaks clothes or, worse, can lead to mineral deposits and rust that transfer to clothes. Instead of filling the iron with water, opt for a separate spray bottle and use that to dampen clothes instead.

Wrapping Technique Prevents Headphone Headaches

Headphone cables tangle more easily over time as coiling them introduces a persistent twistiness, which can also cause them to malfunction. Keep them in working order by following this strategy:



01

Hold your hand as if initiating a handshake, and drape the cord in front of your thumb so the jack rests on your palm.



02

Bend in your last three fingers to hold it in place, forming a pistol shape with your thumb and index finger.



03

Wrap the remaining length of cord around those two fingers in a figure-eight motion. The figure eight reverses the twist with each loop, so every two loops cancel each other out.

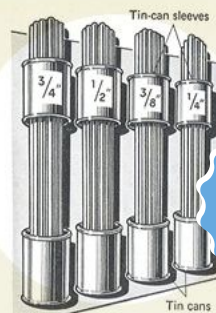


04

When the cord is fully coiled, remove the jack end from your palm and wrap it around the center of the figure eight.

A Dowel Is a Stethoscope for Engine Doctors

Misfiring, bad timing, and other engine problems can be diagnosed by sound. To hear better, use a dowel as a simple stethoscope: Place one end against the engine. Press the other against your ear. Avoid locating the dowel where it can slip into a fan, pulley, hammer mill, etc.



Tin Cans Store Dowels

Pairs of empty tin cans mounted one above the other make storage racks for dowels. Dowels rest in the lower can, and the upper can—which should have its bottom removed—acts as a retainer to keep them upright. Space the cans as appropriate for the length of the dowels to be stored, and mount them on garage studs, the back of a door, or a sheet of plywood, to be hung wherever is convenient.



Improvised Rubber Mallet

For work that requires softer or non-marking impacts, a typical claw hammer can be transformed into a makeshift rubber mallet with a tennis ball. Use a utility knife to cut an X in the tennis ball, then slip it over the head of the hammer.

Putty Knife Protects Wall

Tired of scuffing or scratching a surface when removing nails? Slide a putty knife under a nail before using a claw hammer to remove it. The hammer rolls against the knife, preserving the surface.

**HANDLE
YOURSELF
WITH
CONFIDENCE
AND
STYLE**

**ANYWHERE.
ANYTIME.
WITH
ANYONE.**

Got a sudden stain on your perfect white dress shirt—just before an important meeting? Need to order a drink for your date? Concerned about how to manscape, buy the perfect gift, leave a dull party gracefully, or navigate the intricacies of any social event? *Esquire's The Biggest Black Book Ever* shows you how to do everything right, in every area of your life.



**AVAILABLE
WHEREVER
BOOKS
ARE SOLD**

\$24.95 (\$27.95 CAN) IN HARDCOVER

HEARST
books



Actual size
is 40.6 mm

Advance Release: Order Your New U.S. 2016 Silver Dollars Now!

Millions of people collect the American Eagle Silver Dollar. In fact it's been the country's most popular Silver Dollar for thirty years. Try as they might, that makes it a very hard "secret" to keep quiet. And right now, many of those same people are lining up to secure the brand new 2016 U.S. Eagle Silver Dollars — placing their advance orders now to ensure that they get America's newest Silver Dollar just as soon as the coins are released by the U.S. Mint in January. Today, you can graduate to the front of that line by reserving your very own 2016 American Eagle Silver Dollars — in stunning Brilliant Uncirculated condition — before millions of others beat you to it.

America's Brand New Silver Dollar

This is a strictly limited advance release on the 30th anniversary of one of the most beautiful silver coins in the world. Today you have the opportunity to secure these massive, hefty one full Troy ounce U.S. Silver Dollars in Brilliant Uncirculated (BU) condition. The 100-year-old design features a walking Lady Liberty draped in a U.S. flag on one side and a majestic U.S. Eagle and shield on the other.

The Most Affordable Precious Metal— GOVERNMENT GUARANTEED

Silver is by far the most affordable of all precious metals — and each full Troy ounce American Eagle Silver Dollar is government-guaranteed for its 99.9% purity, authenticity, and legal tender status.

A Coin Flip You Can't Afford to Lose

Why are we pre-releasing the most popular Silver Dollar in America for a remarkably affordable price? We're doing it to introduce you to what hundreds of

thousands of smart collectors and satisfied customers have known since 1984 — GovMint.com is the place to find the world's finest coins.

Lock In Your Reservation

By calling today, you can reserve some of the very first brand new Brilliant Uncirculated 2016 American Eagle Silver Dollars. Your reservation and price will be locked in, and your stunning new Silver Dollars will be shipped to you just as soon as the U.S. Mint releases the coins in January.

30-Day Money-Back Guarantee

You must be 100% satisfied with your 2016 American Eagle Silver Dollars or return them within 30 days of receipt for a prompt refund (*less s/h*). Don't miss out on this exclusive advance release. Call immediately to secure these American Eagle Silver Dollars ahead of the crowd.

**2016 American Eagle Silver Dollar BU
Shocking Low Price \$17.95 ea.**

(*plus s/h*)

LIMIT 10.

Additional 2016 Silver Eagle BU Dollars may be purchased for \$18.95 each. Limited to 50 total coins per household.

FREE SHIPPING on 9 or More!

Limited time only. Product total over \$150 before taxes (if any). Standard domestic shipping only. Not valid on previous purchases.

For fastest service, call today toll-free

1-800-969-0686

Offer Code ESB147-05
Please mention this code when you call.



GOVMINT.COM®

GovMint.com • 14101 Southcross Dr. W. Dept. ESB147-05 • Burnsville, Minnesota 55337

Prices and availability subject to change without notice. Facts and figures deemed accurate as of November 2015. NOTE: GovMint.com® is a private distributor of worldwide government coin and currency issues and privately issued and licensed collectibles, and is not affiliated with the United States government. GovMint.com is not an investment company and does not offer financial advice or sell items as an investment. The collectible coin market is speculative, and coin values may rise or fall over time. All rights reserved. © 2015 GovMint.com.

THE BEST SOURCE FOR COINS WORLDWIDE™

Saving People Money Since 1936

**... that's before there were
modern turn signals.**

GEICO has been serving up great car insurance and fantastic customer service for more than 75 years. Get a quote and see how much you could save today.

geico.com | 1-800-947-AUTO | local office

GEICO®



**Getting
Started
In...**

ICE FISHING

Just because it got cold doesn't mean the fish have left. **BY C. J. CHIVERS**



MY DAUGHTER ELIZABETH

stood on the frozen surface of a lake near our home, peering intently at the hole at her feet. It was a Saturday during the bitter winter of 2015, and she was holding a remarkably short fishing rod, dangling a metal jig down into the gin-clear water. The jig, spiced with a mealworm, was perhaps 16 feet beneath her, just above the lake's bottom.

Under a roof of ice, this little lure-and-bait combination was darting upward, then fluttering and falling, again and again. Elizabeth was trying to entice a fish to strike. I had turned away to scan rows of fish traps when she called out. I looked back to see the little rod bent, Elizabeth cranking on its reel. Soon she hoisted a fine yellow perch into the air. It was perhaps 11 inches long, its bright-orange pectoral fins set against a barred yellow-and-green flank. The fish was plump, bulging with eggs. An eater, all around. Elizabeth set it on the snow beside others. The cold water was yielding its midwinter gems, and we would be having a fish fry in our house tonight. There was not another soul in sight.

Our solitude was no surprise. One old joke about ice fishing is that it is a sport many people try once. It's partly rooted in truth, and for good reason: To those who have not been introduced to the particulars of harvesting a frozen lake's bounty, the ice can be a foreboding and impenetrable place. Divining how to bring home fish from water that you can barely see can seem confounding. Where to fish? And how? For what? With what equipment? How do you stay comfortable and safe?

The questions might sound daunting, but most of the answers are simple.



1

Safety

Plunging through weak ice into frigid water (often deep frigid water) is more than miserable. It is a quick way to die.

Testing the Ice

Local bait shops will know the conditions, but you can double-check ice thickness by piercing it with a chisel or a cordless drill. There are several old-timers' rules out there about ice thickness and safety—2 inches will support a man, 6 inches a snowmobile, 10 inches a pickup truck. I add at least 50 percent to these estimates to account for variations in ice strength and thickness. I started ice fishing around age three or four. Almost a half-century on, you'll not find me on ice thinner than 3 inches. I feel much more comfortable at 4, and late in the year, as ice rots with spring-like weather, I am even more cautious, as even thick ice can get soft.

Not all ice is the same. Moving water generally does not form strong ice, if it forms ice at all. For this reason, rivers are generally to be avoided, except in protected coves.

TIP!

The easiest problem to handle is the problem you foresaw and avoided. If there are any doubts about ice thickness or safety—as there inevitably will be early and late in winter, and during long thaws—stay on shore.

Safety Equipment

Some anglers add a host of safety equipment to their kit, including metal cleats for their boots, a life preserver, a whistle, hand spikes, and a rope with knots or a loop at the end attached to a buoy or throw cushion that can be tossed to anyone who falls through. I carry an ice spud—a heavy steel bar about 4 feet long, with a tapered blade at its end. When venturing onto new water, I tap this ahead of me on the ice. Firm ice responds with a sharp, solid, and reassuring noise. Your ear becomes attuned to the sound.

CLEATS
Kahtoola
Microspikes
\$70



TIP!

You'll be on your feet all day, so be sure your boots are comfortable. And warm. Sorel's Caribou XT boots (\$160) are wind- and waterproof. Your feet won't know they've left the living room.

2

Comfort

YOU'LL NEED WARM clothes in layers, insulated and waterproof boots and gloves, a good hat, and maybe a hood too. Goggles are a smart investment to protect eyes from glare and stinging snow.

Ice-fishing trips can be as spartan or as fancy as you wish. My children and I tend toward spartan, and walk out on the ice dragging sleds with the kit and a bucket or cooler of live bait, sometimes adding a backpack or two with a thermos of coffee and food. Others build shanties to live in, or roll across the ice on snowmobiles or pickup trucks loaded with equipment, food, and gas grills.



3

Where to Fish

YELLOW PERCH, WALLEYE, trout, pike, crappie, sunfish, largemouth bass—these are staples of many ice-fishing trips. If a pond or lake has a healthy number of fish when it's not frozen, it'll have a healthy number when it is. Some lakes are better than others. (Good options include Lake Michigan, Vermont's Lake Champlain, and nearly anything in northern Minnesota.) Local bait-and-tackle shops can steer you, as can other ice fishermen (who are

helpful online at iceshanty.com).

The best-known destinations can become crowded and carnival-like, especially at tournaments. (See above. Avoid.) But many other lakes, like the one where Elizabeth hauls perch, are quiet and still, and we usually encounter no one at all as we fish in what amounts to a standard fashion, with some of us setting traps while others move from hole to hole with a jigging rod, looking for fish.

↑
FRABILL
ICE
CHISEL
\$25

4

How to Fish

BAIT GUIDE

Successful ice fishing lies in smart bait selection.

BAIT



mealworms or grubs

FISH



sunfish



large minnows



largemouth bass



small minnows



perch



large minnows or perch



pike



Cutting Holes

Forget about casting. Ice fishing starts with cutting holes. Many holes. To do so requires either a spud (opposite page) or an auger, a large drill powered by hand or by a small motor. We use a spud in the early season (for

chipping out holes) and a power auger once the ice becomes thick. There are several prominent auger brands, with disputes between adherents that rival Ford-Chevy debates. Just like a drill bit, the auger's diameter

determines the width of the hole. Six inches is fine for most fishing, 8-inch augers are popular, and if you're on a lake with huge fish, a 10-inch auger might make sense. But beware: A wider diameter means more work.

Rods vs. Traps

Once you've cut holes, you have two primary means of fishing: with a rod or via traps. Rods are used for vertical jigging, or lightly bouncing the bait in the water, and dangling live minnows or small grubs. They tend to be short and simple—so basic that some people don't even use a reel and make jigging sticks in woodshops at home. More than a few old shovel handles or hockey sticks have been repurposed this way. My favorite rod is the handle and piece of a spinning rod we broke by accident about 35 years ago. It works fine.

Different waters have different rules for how many traps an angler can put out. Five per person is common, though we have fished one lake that allows 15.

When a fish takes the bait, its movement spins a spool of line, triggering the release of a small flag, indicating a strike. The angler then runs to the trap, takes up the line with fingers, sets the hook, and plays the fish hand over hand.

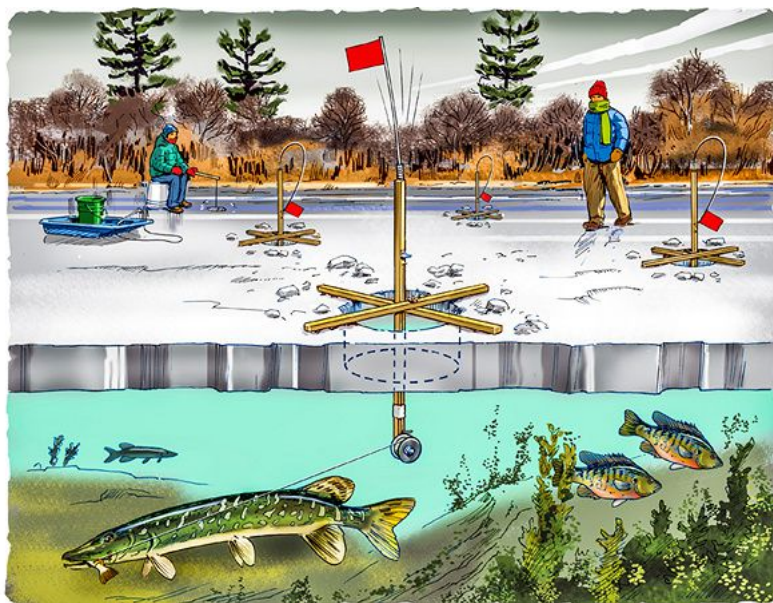
Every winter there are days when you end up unable to keep all the tip-ups set because you can't find the time, running from flag to flag, to rebait them. These are the trips you remember, and the reason you're out there. Once you hit that zone all you need are two more things: a sharp fillet knife and recipes.

How Traps Work

Traps, also known as tilts or tip-ups, are renowned for hooking monster fish. They suspend a large bait for hours in areas where an old, big fish might lurk. When arrayed along drop-offs or large weed beds where game fish often prowl, traps let ice fishermen cover far more water than they could with a single rod and erase the handicap of not being able to cast.

TIP!

Saturation comes with costs. The more tip-ups you put out, the more work you face, and not just cutting the holes. Traps must be tended. Holes in the ice freeze on cold days, or become buried in drifting snow. You must continually check your line of traps, and often change the bait.



ASK ROY

POPULAR MECHANICS' SENIOR HOME EDITOR
SOLVES YOUR MOST PRESSING PROBLEMS.
BY ROY BERENDSOHN



Q My frequent remodeling jobs make our house filthy. The dust bags on my power tools don't help. Neither does hooking them up to a shop vac. Are there any other solutions?

LARRY T., DES MOINES, IOWA

A The dust bag and shop vac ideas are a good start, but you need a multipronged approach. If weather permits, do your wood cutting outside. Sweep up any loose sawdust that you've created before it gets blown all over the yard or back into the house. If you are working inside, use a ZipWall to contain dust and debris in the work area. The sophisticated pole-mounted system (\$140) suspends plastic sheeting from the ceiling to the floor, isolating the work area from the rest of the house. Plus, the static cling on the plastic traps some airborne dust. Take frequent clean-up breaks, especially to remove debris from underfoot, where it gets worked into your footwear, then tracked around the house. Keep a heavy-duty garbage can near the work area for easy debris dumping.

This last suggestion might strike you as over the top, but it's effective. Really fastidious contractors use 3M Dirt Catcher Super Sticky Mats at the entrance of work areas. Each mat is like a gigantic piece of tape that pulls fine dust off your shoes when you exit the work area. When the top sheet on the mat no longer grabs,

you peel it off to expose the sheet below. They're about \$20 to \$30 for a pack of 15. And they work.

Q We tried to refinish our coffee table but accidentally sanded through the top layer of wood veneer. What do we do?

CARL B., LOS ANGELES

A The simplest solution is to hide the damage with pigmented finish like Minwax PolyShades, a combination stain and polyurethane. Each coat darkens the surface and makes the damage less visible. To apply, pour the finish out of the can and into a disposable plastic paint pot, being sure to get any thickened material off the bottom of the can. Stir the finish gently but thoroughly, then use a soft, natural-bristle brush to apply thin layers in long, slow, and gentle strokes. Finish each coat by holding the brush at 45 degrees and very lightly dragging the bristles over the freshly applied surface.

Let the finish dry. The amount of drying time varies with temperature and humidity, but typically it's six to eight hours. Then, using No. 000 (extra-fine) or No. 0000 (finest) steel wool, go over the surface to remove any roughness and imperfections. Apply another coat. Continue

until you've adequately hidden the damage.

Q We were awakened on a cold winter night by a loud crackling sound coming from somewhere in the house. We searched but couldn't find anything amiss. Any idea what it could have been?

LINDA N., BURLINGTON, VERMONT

A My hunch is that you've got ice formation somewhere inside the house and that it gave way in the middle of the night. Ice can form in the attic when a vent from a bathroom fan leaks. The vapor condenses and creates a large icicle. Ice can also build up inside walls, especially if there's a gap that admits cold outside air and there's a source of moisture, such as a leaking dryer duct. The fastest way to find these cold spots is to use a Seek Thermal imaging camera. The device costs \$250 to \$300 and plugs into the Lightning port or micro USB on your phone. It reads infrared energy emitting from walls, ceilings, floors, windows, doors, appliances—anything. If you don't want to spend money on the Seek, search for these energy leaks the old-fashioned way: with a flashlight, a ladder, and kneepads. You can even look for cracks in hard-to-reach places with a small inspection mirror on an extendable wand. Once you find a leak, seal it and insulate the area to prevent the problem from happening again.

Call 212-649-2828 and leave a message with your home or yard question. You could be featured on a new Popular Mechanics podcast. Questions can also be emailed to askroy@popularmechanics.com.



THE GADGET REVIEWS YOU LOVE. (NOW ON EVERY GADGET)

Subscribe to the *Popular Mechanics* enhanced digital edition and we'll show you how things work... whenever it works for you!

- ▶ Available anytime, anywhere—on any device
- ▶ The upgrade ideas, plus auto, tech & space news you love BEFORE THEY HIT NEWSSTANDS
- ▶ DIGITAL-ONLY features let you share articles & access back issues
- ▶ TABLET-EXCLUSIVE videos, interactive animations & photo galleries

GET ANSWERS FOR TODAY'S TIMES.
ANYTIME.

50% OFF
NEWSSTAND PRICE



Try it on your tablet today at deal.popularmechanics.com



ENGRAVE IT. CUT IT. MARK IT.

The only limit is your imagination.



Your vision combined with Epilog's power equals spectacular creations.

From creating and personalizing 3D models, to laser die cutting pre-printed objects, to marking high-tech gadgets, our laser systems create the products you see here and more! Whether you're working with wood, acrylic, paperboard or just about anything else, Epilog Laser systems precisely cut and etch the components you need.

Desktop Systems Starting at \$7,995

Contact Epilog Laser today for a laser system demo!

www.epiloglaser.com/popmech • sales@epiloglaser.com • 888-437-4564

MADE IN USA
Golden, Colorado



BEST IN CLASS CHALLENGE

During the fall term of 2015, high school auto shops from across the country competed to restore and customize cars in the Quaker State Best in Class Challenge. Five finalists were selected to complete a series of challenges over 6 weeks to determine which school would come out on top. The winning school took home the Grand Prize, a \$2,000 gift card and mechanic's toolkit from AutoZone, and the opportunity to sell their vehicle at the prestigious Mecum Auctions on December 11, 2015, in Austin, TX.



ATLANTA MAXWELL HIGH SCHOOL OF TECHNOLOGY

"IT'S GREAT FOR A BRAND LIKE QUAKER STATE TO REALIZE THE POTENTIAL IN OUR STUDENTS AS THE NEXT GENERATION OF AUTOMOTIVE TECHNICIANS AND GIVE THEM THE HANDS-ON EXPERIENCE THEY NEED TO FULLY REALIZE THE OPPORTUNITIES THAT LIE AHEAD."

– **Max Chavez**, auto shop team leader for Maxwell High School of Technology

QUAKER STATE APPLAUDS THE FINALISTS FOR THEIR HARD WORK AND PARTICIPATION

Orlando Satellite
High School

2nd PLACE

Charlotte Iredell
Statesville Schools

3rd PLACE

Chicago New
Trier High School

4th PLACE

N. New Jersey Kearny
High School

5th PLACE

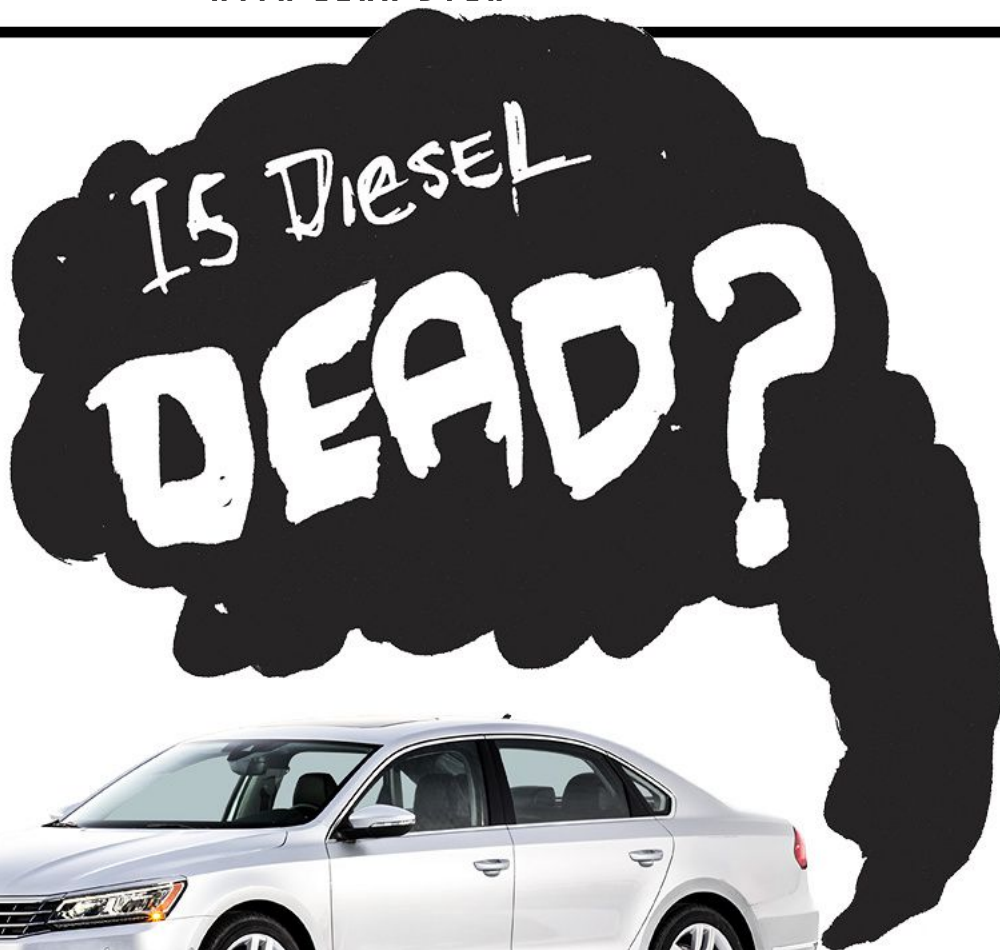
VISIT QUAKERSTATE.COM FOR QUAKER STATE BEST IN CLASS CHALLENGE PROGRAM DETAILS!

Special thank-you to **AutoZone**, **Mecum Auctions**, our judges, **Tommy Pike** of Tommy Pike Customs™, and NASCAR Sprint Cup Series competitor **Paul Menard**.



DRIVING

WITH EZRA DYER



VOLKSWAGEN'S EMISSIONS DEBACLE DIDN'T HELP
THE CASE FOR DIESEL POWER IN THE U.S. BUT IT ALSO DIDN'T HURT.
YOU CAN'T KILL SOMETHING THAT'S DEAD ALREADY.

I am a big proponent of diesel engines. They've got great torque. They're efficient. They tend to last forever. Hey, I converted my own truck from gas to diesel, and I've steered more than a few friends toward diesel purchases. (If you don't dig a Mercedes-Benz GL350 BlueTec, then I don't understand what you want in a family SUV.) But even I have to admit that diesel in the U.S. is a tough sell. And Volkswagen made it tougher.

There are plenty of reasons diesels are niche products in the U.S. For one thing, there are our emissions priorities: The EPA hates nitrogen oxide (a diesel bugaboo) but doesn't care about CO₂, where diesel engines hold an advantage. Diesel fuel is generally more expensive than gasoline. And while every gas station has gas (duh), you might have to drive around to find a diesel pump when you need it. Put these factors together and you end up with a car that has an elab-

orate and expensive emissions system, running on pricey fuel that's not available at every pump. And for what? Given the existing rules, diesel didn't make a case for itself. So VW bent the rules until it did.

The Chevy Cruze—available with gas or diesel power—is a prime example of the challenge that faces diesel passenger cars. Namely, we've gotten so good at building efficient gas engines that the traditional diesel advantage is practically gone. A diesel-powered 2015

Cruze earns an EPA combined rating of 33 mpg. The thirstiest gas-powered version, the Cruze Eco, gets an EPA combined rating of... 33 mpg. The diesel offers slightly more horsepower and a lot more torque, but the mileage numbers don't seem to justify its existence. Neither do its sales, and the Cruze diesel is on what GM describes as a temporary hiatus during the rollout for the new 2016 Cruze. A diesel model is supposed to return in 2017, but I wouldn't bet on it.

The on-again, off-again diesel Mazda6 is another car waylaid by the U.S. diesel environment. According to its original plans, Mazda should've already been selling a diesel 6. I asked Mazda whether that car is still in the works, and the response is yes, with a caveat: They'll sell it once they're happy with both the fuel economy and performance. "While we could meet the standards, overall performance and economy suffered," says Jeremy Barnes, director of public relations for Mazda North America. "When we made the car drive like we wanted it to, emissions performance suffered. Without after-treatment, performance and emissions were mutually exclusive. And because the Skyactiv engine was built to operate without after-treatment, adding it on wasn't simply a case of bolting a system in and calling it good."

So they're still planning for a U.S.-compliant diesel, but there's no timeline for a solution. Meanwhile, the gas Mazda6 gets 40 mpg highway and is excellent to drive. So what's the threshold for a viable diesel—50 mpg? That's the mileage I saw in a Jetta SportWagen TDI that, as we now know, had its emissions systems lying dormant. The mileage ceiling for an hon-

est emissions-compliant diesel seems to be in the mid-40s. And is that really good enough?

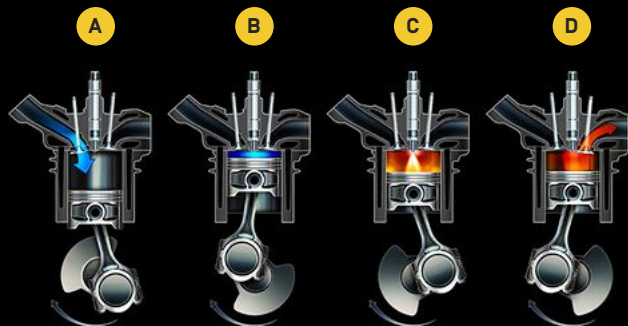
A former VW salesman, Matt Train, told me that his diesel customers were always the true believers, and the general public just wasn't interested. "Most people I dealt with couldn't be bribed into looking at a diesel," Train says. "And after driving a Prius for three years I just don't see how diesel will remain relevant. VW did more damage to diesels than GM did in the 1970s," he says, citing GM's regrettable foray into diesel cars. "And that's saying something."

DIESEL OFFERS A LOT MORE TORQUE... BUT THE MILEAGE NUMBERS DON'T SEEM TO JUSTIFY ITS EXISTENCE.

There is still a growth market for diesel in America, however: trucks. Diesels have a tough time eking out an advantage in small cars, but their low-revving, high-torque power delivery is perfect for trucks. The Ram EcoDiesel, the first light-duty diesel pickup on the market, earns a 29-mpg highway rating and can tow more than 10,000 pounds. Eco-minded car buyers have plenty of options—hybrid, plug-in hybrid, high-efficiency conventional gas models—but trucks are a different story. In that world, diesel is still a smart option, which is why Nissan, Land Rover, and Chevrolet all have new diesels coming to market (in the Titan, Range Rover, and Colorado, respectively). The new Range Rover TDV6 diesel gets 32 percent better fuel economy than the gas V-6. That's a no-brainer: Get the diesel.

For cars, though, I agree with Train, the former VW salesman. Diesel is probably done. Volkswagen's reckless regulatory end run proves that building a saleable small diesel isn't just hard. It might be impossible.

A BRIEF PRIMER



HOW DIESEL WORKS

The intake stroke (A) draws only air, no fuel. The compression stroke squashes that air (B), creating pressure, which creates heat. Once the air in the cylinder is hot enough to ignite, fuel is injected (C). There's no throttle plate—a diesel is effectively always at wide-open throttle—and engine speed is a function of how much fuel you throw at it. Diesel burns slower than gas, so that limits how high it can rev. On most modern diesels, the exhaust stroke (D) typically sends the spent gases to an after-treatment system to neutralize oxides of nitrogen.

INSIDE THE ROAD TRIP THAT BROUGHT DOWN VOLKSWAGEN



In 2013, **Arvind Thiruvengadam** and **Marc Besch**, engineers from West Virginia University, took a road trip from Los Angeles to Seattle in the hope of logging the exemplary efficiency of diesel passenger cars. What they found ended up exposing VW's unconscionable deceit.

Volkswagen was never on the initial proposal. We just chose the vehicles based on the technology they contained. The Volkswagen Jetta was the only one that had the technology we needed to assess. For the other tests, we were able to procure a Volkswagen Passat and a BMW X5.

Before we actually took the vehicles out on the road, we tested them in the laboratory. They were working as they're supposed to. Emissions were low. Immediately after we left the California Air Resources Board facility, we started seeing emissions we couldn't explain. We knew when the systems were supposed to work and when they weren't, and there was no logical explanation.

We were renting the vehicles and paying a lot of money, so we had three days for the whole trip—there and back. We didn't take any breaks. We just took turns continuously driving. On the first night when Marc was driving, we were in Oregon and it was raining. We wanted to visit the Boeing Factory, so we stopped and did the Boeing tour and that was the only thing we did other than test the cars.

Marc started the data post-processing a couple of months later. He discovered the problem then. We didn't realize that we were uncovering something, because we expect problems during real-world testing. Every manufacturer has design flaws at some point, so we thought it was probably just that.

In December 2014 we were informed that VW would do a voluntary recall. We thought that was our biggest achievement, that our study helped VW identify some problems. We were happy then. Now we have a different kind of recognition. It's international. It's been phone calls after phone calls.

—As told to Lara Sorokanich



✓Yes



✓Yes



✗No



✓Yes



✓Yes



✓Yes

- ✓ Reliably Low Prices
 - ✓ Easy To Use Website
 - ✓ Huge Selection
 - ✓ Fast Shipping
- www.rockauto.com



10 CIGARS + HUMIDOR

Only \$29.99

Cigar.com/CGSA602

Enter full web address for offer

CALL 800.357.9800

Mention CGSA602

Offer expires 3/31/16

Here's an offer you can't refuse. For this special introductory offer we put together our favorite cigars and cut the price over 73% off MSRP. Sound too good to be true? Well, it gets better. We also threw in a premium Spanish cedar-lined, mahogany finished 40-capacity humidifier at no extra cost. This deal is only available for a limited time and you won't find these cigars discounted this much anywhere, so act now! Sampler includes a free humidifier and one each of the following: Rocky Patel Decade, Montecristo Media Noche, Casa Magna, CAO Brazilia, Oliva Serie 'O', Alec Bradley Prensado, Cohiba Red Dot, Macanudo, Gurkha Centurion, and Romeo y Julieta Vintage. A \$203 value!

Cigar.com
The Home for Cigar Enthusiasts

*Please add \$6.99 s/h. Taxes on orders shipped outside of PA are the responsibility of the purchaser; PA residents add 6% tax. Available to new customers only. One per customer. From time to time substitutions may occur. Cigar.com does not sell products to anyone under the age of 21.

Cigar.com | 1911 Spillman Drive | Dept. #26 | Bethlehem, PA 18015

The Supercar Road Trip

WHEN YOU TAKE A LAMBORGHINI AVENTADOR SV ON A 700-MILE DRIVE, YOU PLAN ON A FEW THINGS: THE SPEED, THE THRILL, AND THE CONSTANT ATTENTION. BUT NOBODY MENTIONED THE BACK PAIN.



For some reason, the digital clock in the gauge cluster reads September 20, 2000. Factory glitch. This is appropriate, because the Lamborghini Aventador Superveloce is a time traveler of sorts, a car that evokes a bygone conception of an exotic: the definitive Lambo. Like its predecessors—the Countach, Diablo, and Murciélago—the Aventador

SV is an impossibly wide, ridiculously low-slung blade of a car, with doors that scissor skyward and a huge V-12 behind the seats. That is the formula. On the cover of his album *Mack Daddy*, Sir Mix-A-Lot poses with a Diablo, its open door pointed to the heavens. That was in 1992, but it could've been 1982 or 2002, because the top-flight Lamborghini is always on the scene, so long as that scene demands a commitment to

shameless decadence. It's a car for all ages. Except, maybe, this one.

The Superveloce seems like a vehicle that should no longer exist. In an era when Porsche, Ferrari, and McLaren build plug-in hybrids, the Aventador gets 13 mpg. While a Volkswagen GTI uses a silken dual-clutch transmission, the SV crashes through the gears with a single-clutch automated manual. Long ago, the Acura NSX proved



The author nears his destination in Miami. Open roads are a constant exercise in self-restraint when your right foot commands 740 horsepower.

that comfort and performance are not mutually exclusive, and yet this half-million-dollar Lamborghini includes no stereo, cruise control, or carpeting. It's just a bundle of muscle thrumming with anger, and that's before you even start the thing.

The only reason I notice that nobody set the clock—which would be annoying in a Lexus but is somehow charming in a Lambo—is because I have plenty of time to gaze about the Aventador's stripped-down cabin en route from North Carolina to Miami. An 11-hour road trip in a car that prioritizes speed above all else should be interesting. And, in many ways, challenging. A full day in a Superveloce forces you to examine your own passion: How much do you really love cars?

I don't dare complain about my plight, but let me explain the ways in which the Superveloce is ill-suited to a super-long voyage. The seats are carbon-fiber shells covered in the barest suggestion of padding, with no adjustment except for back and forth. It's like sitting in a melon scoop. The lack of a radio isn't really a problem, since you wouldn't be able to hear it anyway over the constant thrum of road noise. Visibility out the back is nearly nil, and there's no rear-view camera. There's also no USB port, which means if you forgot your charger, like I did, using Waze to navigate and find the inevitable cops will quickly drain your phone. In the language of Lamborghini, there are 50 words for speed and no word for cup holder. It's almost as if they never expect anyone to drive this thing 700 miles on the highway.

I try to avoid the interstate when I can, because highway travel denies you the opportunity to meet the fans. And this car has fans wherever it goes. Early on, I'm driving back roads when an Accord pulls up next to me at a light and the woman at the wheel informs me she's been following me for 20 miles just to find out what this car is. In Charleston, South Carolina, a school bus full of kids looks like it might tip over, so fast do they all rush to one side to gawk at the Lamborghini. At a Starbucks in Florida,

I walk in and the guy at the counter informs me, "There are two women in here who want a ride in that car. So far." You grow accustomed to glancing out the window and seeing phones pointed at you. You don't want to pick your nose in an Aventador Superveloce. Someone will get it on video.

The constant attention is on my mind every time I get the urge to let 'er rip. And that urge presents itself seemingly every mile or two, each time there's a gap in traffic and a cop-free sight line. Superveloce means "super fast" in Italian, and it's not false advertising. The 6.5-liter V-12 revs so fast that you really need to use the transmission's automatic mode for full-throttle upshifts—using the paddles, it's a fine line between

upshifting early and banging into the rev limiter as the engine flashes past 8,000 rpm. I air it out a few times, but never for long. This car can do zero to 186 mph in 24 seconds, so flattening the accelerator is an exercise in willpower, a game of chicken against the oncoming specter of bad consequences. My personal high score, top-speed-wise, is 206

mph, and the SV could obliterate that pretty easily. Are there any salt flats or dry lakes en route to Miami? Because that's what I need. If you can afford \$493,095—taxes and delivery included!—then perhaps you can afford to book a facility where you might test Lamborghini's top speed claim, which is "faster than 217 mph."

By the time I get to southern Florida, I have the posture and gait of a wizened mountain hermit emerging from his cave. But I've grown fond of the Aventador in spite of its brutal demands. I now know how to back it up while sitting on the sill with the door open, like I've seen the factory test drivers do in Italy (thus solving the visibility issue while looking preposterously badass). I know that the fuel-saving cylinder deactivation works only up to 87 mph. I know how to play the exhaust note like an instrument, using the paddle shifters and accelerator. Most modern supercars adapt to their drivers, but in the SV that situation is reversed. It makes no apologies for its Lambo-

YOU DON'T WANT TO PICK YOUR NOSE IN AN AVENTADOR SUPERVELOCE. SOMEONE WILL GET IT ON VIDEO.



From top: The more powerful your car, the more frustrating it is to sit in traffic; every gas station stop meant making new friends; the only company—other than stares—for seven hours on the road.

ness. Presumably, you knew what you were getting into.

And what I'm getting into, down in Miami, is a Porsche 911. Three of us are going out to dinner, so I pile into one of the Porsche's backseats. It is, without exaggeration, more comfortable than the Superveloce's driver's seat. We head out into traffic, and nobody looks twice.

ROAD TRIP CHECK-LIST

(In descending order of importance)



keys



phone charging cable



water



snacks



water bottle (for traffic jam emergencies)



destination

BASE PRICE

\$51,395

EPA MILEAGE:

15 mpg city/
19 mpg highway

BASE PRICE

\$30,875

EPA MILEAGE:

19 mpg city/
27 mpg highway

BASE PRICE

\$21,195

EPA MILEAGE:

26 mpg city/
34 mpg highway

REVIEWS

1

2016 HONDA PILOT

➔ The Pilot has a nemesis and its name is Odyssey. They're close relatives, so differentiation is the perpetual challenge: How do you bake the same cake two ways to appeal to entirely different groups of people? The last time around, Honda went butch with the Pilot, tall and upright, with a stress on off-road performance. And indeed, when we took that Pilot out on Michigan's Silver Lake dunes for a comparison test, it fared just fine on the sand. The pavement, though, was a different story. At Chrysler's Chelsea, Michigan, proving grounds, the Pilot distinguished itself as the only vehicle that looked like it might flip over during the lane-change test.

This new Pilot seems to embrace rather than disavow its Odyssey connection, which makes sense. People who are shopping crossovers aren't going to buy a minivan anyway, and vice versa. So **the Pilot is longer, lower, and 286 pounds lighter, with a third-row seat that adults can actually use.** It's got 30 more horsepower (now 280) and an available nine-speed automatic. It's far more enjoyable to drive, and it retains the crucial feature unavailable to Odyssey buyers: all-wheel drive. Even if off-roading is a fantasy, the new AWD system includes a torque-vectoring rear diff that helps point the front end into corners. The last Pilot might've been happier on the dunes, but this one is far better where people will actually notice: on the road.

2

2016 LAND ROVER LR4

➔ The Land Rover LR4 is such a guilty pleasure. It's a rig that will take seven people deep into the boonies in utmost comfort. It'll tow a boat (a big one). Take it to a football game and you can lower the air suspension and drop the tailgate—yes, it actually has a tailgate—to set up a pregame headquarters. And because its gross vehicle weight rating is above 6,000 pounds, it's classified as a "heavy SUV," which means that if you use it for business you can write off up to 91 percent of the depreciation in the first four years. Consult your tax professional on that one.

Heavy SUV, though—that's where the guilt comes in. Last year **Land Rover replaced the LR4's 5.0-liter V-8 and six-speed automatic with a 3.0-liter supercharged V-6** paired with the ZF eight-speed. The 340-horsepower V-6 concedes some muscle to the V-8, but it feels nearly as quick thanks to the extra gears and the supercharged low-end torque. The numbers still aren't great (15 mpg city and 19 mpg highway), but the new powertrain delivers a 14 percent improvement over the V-8. Still, that sub-20-mpg highway rating shows that there's only so much you can do when you're propelling a studio apartment down the road.

With a price starting around \$51,000, the LR4 is, oddly enough, a clear value. Whether you could drive it with a clear conscience is up to you.

3

2016 CHEVROLET TRAX

➔ The last Buick Encore I drove cost nearly \$30,000, a price that seemed ludicrous for a dressed-up Chevy Sonic. The Trax is still a Sonic moonlighting as a crossover, but it carries a much more reasonable sticker—under \$21,500. That's a fair deal for an unassuming, unremarkable little wagonette with a turbocharged secret under the hood.

While the Sonic comes standard with a buzzy, naturally aspirated four-cylinder, the Trax is available only with the upgrade engine option, a 1.4-liter turbo. Given the look of the thing, your expectation for fun is effectively zero, and yet the **138-horsepower four-cylinder endows the 2,800-pound Trax with surprising punch.** You can drive everywhere at full throttle without anyone noticing, which is a nice attribute for those of us with a few points on our licenses.

According to GM, nearly half of Trax buyers have never owned a Chevy, so this is their first exposure to the brand. As such, it's crucial to make a good impression. And that it does, mainly by way of the personality imbued by that spunky engine. I'd still go for a Sonic—same size, less money, available six-speed manual. But if nothing else, the Trax will bring a good number of first-time Chevy buyers back to the dealer when the lease is up or they're ready for something bigger. So, you liked the Trax. May we show you the Equinox?

THE FIVE-WORD REVIEWS



2016 FORD MUSTANG GT CALIFORNIA

Exhaust seems louder. That's good.



2016 MITSUBISHI I-MIEV

Powerful! Comfy! For 62 miles.



2016 LEXUS IS200T

Enthusiasts: Get the big V-6.



FREE

Awning Idea Kit and DVD

- Cool Shade in Seconds
- 99% UV Protection
- Great Relaxation and Entertainment Spot
- Exceptionally Affordable — Prices as Low as \$499!
- Saves Energy, Helps Cut Air Conditioning Bills
- Motorized & Manual Models
- Easy to Use, Totally Retractable
- Screen Rooms
- Many Exciting Accessories
- Many Designer Color Choices
- Unsurpassed Quality
- 5-Year Limited Warranty
- No Risk Home Trial
- A Must Have for Decks and Patios

Learn how to transform an ordinary deck or patio into a beautiful, shaded outdoor room — a cool, protected retreat where you and your family will love to spend time.

SunSetter, the #1 best-selling awnings in America for over a decade, invites you to call, email, or send today for our **FREE Awning Idea Kit and DVD**. Discover how to outsmart the weather and protect your family while you turn your deck or patio into your favorite 3-season outdoor room — a lovely focal point of your home and a center for outdoor enjoyment.

A SunSetter puts you in control of the weather on your deck or patio. Relax and entertain outside anytime you want without worrying about hot sun, harmful UV

rays or passing light showers. It can be up to 20° cooler under your awning! A SunSetter gives you far more cool shade and protection than a tippy patio umbrella — yet it's so affordable you'll wonder why you waited so long to get one. **Get your Free Idea Kit and DVD today.**

SunSetter®
RETRACTABLE AWNINGS

Find out more with absolutely no obligation. Get your **FREE Awning Idea Kit and DVD** in any of 4 simple ways:

- 1. Call Toll Free: 1-800-876-8060, ext. 31567**
You can call 24 hours a day, seven days a week.
- 2. Email to ideakit@sunsetter.com**
Be sure to include your full name and mailing address.
- 3. Go to www.sunsetter.com**
- 4. By Mail:** SunSetter Products, Dept. 31567
184 Charles Street, Malden, MA 02148. Be sure to include your complete mailing address and email address.



WeatherTech®

American Manufacturing *Done Right!*



FloorLiner™

Provides "absolute interior protection"™

Laser measured to perfectly fit your vehicle

Has channels to carry fluids and debris to a lower reservoir

Material provides soft touch top, rigid core strength and bottom surface friction



Available in Black, Tan and Grey for Cars, Trucks, SUVs and Minivans

All-Weather Floor Mat



Underside Nibs and Anti-Skid Ridges



Ribbed Design

Deep sculpted channels designed to trap water, road salt, mud and sand

Will not crack, curl or harden regardless of temperature

Available in Black, Tan and Grey

Cargo/Trunk Liner

Complete trunk and cargo area protection

Digitally designed for each application

Remains flexible under temperature extremes



Available in Black, Tan and Grey for Cars, SUVs and Minivans



CargoTech®

Cargo containment system

Couples a durable plastic "fence" with a super-grippy underside to keep cargo stable

Excellent for cargo area organization

Works with WeatherTech® Cargo Liner or existing vehicle carpet or flooring

Accessories Available for

Acura · Audi · BMW · Buick · Cadillac · Chevrolet · Chrysler · Dodge · Ferrari · Ford · GMC · Honda · Hummer · Hyundai · Infiniti · Isuzu · Jeep · Kia · Land Rover · Lexus · Lincoln · Maserati · Mazda · Mercedes-Benz · Mercury · Mini · Mitsubishi · Nissan · Oldsmobile · Plymouth · Pontiac · Porsche · Saab · Saturn · Scion · Subaru · Suzuki · Toyota · Volkswagen · Volvo · and more!



TechLiner® and Tailgate shown

TechLiner®

ARMOR YOUR INVESTMENT

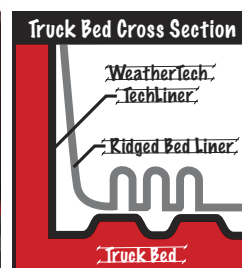
Fits to the exact contours of each application

No messy sprays or drilling needed

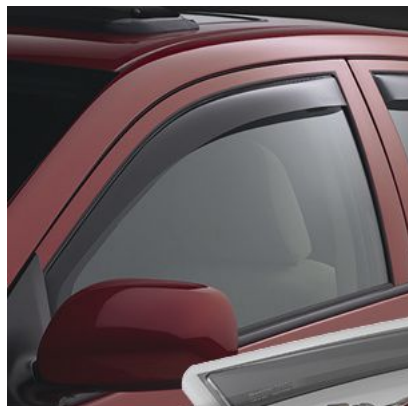
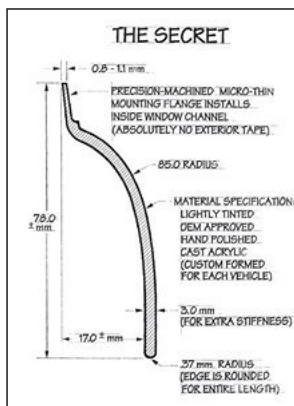
100% recyclable, odorless material

Flexible and durable

Chemical and UV resistant



Side Window Deflectors



EASY TO INSTALL!

No Exterior Tape Needed

Increases ventilation

Reduces wind noise and allows interior heat to escape

Designed and Engineered in USA - Handcrafted in Germany



Light and Dark Tint Available

No-Drill MudFlaps



Mounts-In-Minutes™

Protect your vehicle's most vulnerable rust area

Installs without tire/wheel removal

No drilling into the vehicle's fragile metal surface

Available for Trucks and SUVs



BumpStep®

Protect your bumper from minor accidents

Fits standard 2" receiver hitch

Safely stand on the step (up to 300 lbs.) for everyday tasks

See the video at WeatherTech.com!

Order Now: **800-441-6287**



American Customers
WeatherTech.com



Canadian Customers
WeatherTech.ca



European Customers
WeatherTechEurope.com



THE HYBRID WOODSTOVE

COMPANY

Woodstock Soapstone

LOCATION

West Lebanon,
New Hampshire

FOUNDED

1978



Workers at Woodstock Soapstone's New Hampshire factory. Roughly 700 orders for the Ideal Steel Hybrid are expected this winter.

AS LONG AS MAN has burned wood, that wood has released hazardous substances into the air—naturally produced, sure, but still awful for you. Benzene. Formaldehyde. Ultrafine flecks known as particulate matter that burrow deep into the lungs. And until the Environmental Protection Agency finally took action in 1988, woodstoves spewed the stuff at an incredible rate. A single one could pump out 60 grams of particulate matter per hour—nearly twice that of a 14-ton diesel truck. The EPA's intervention set the legal limit at 7.5 grams per hour. An improvement but still too weak considering the agency released an unrelated study around that same time suggesting that the cancer risk from woodstove emissions might be 12 times greater than that from an equal amount of cigarette smoke.

Yet there the limit remained for more than two decades. So, in November 2013, *Popular Mechanics*, along with the Department of Energy and others, cosponsored the Wood Stove Decathlon. Fourteen teams from around the world traveled to Washington, D.C., to fire up their inventions. The Denmark contingent took the innovation category, and the Germans finished first in efficiency. But the \$25,000 overall prize went to a company in West Lebanon, New Hampshire, called Woodstock Soapstone.

The company, which has been making stoves since 1978, was an early adopter of the catalytic combustor, the honeycomb-shaped filter that incinerates particulates and that eventually became an industry standard. And in 2011 it introduced the first hybrid-combustion stove, adding a secondary combustion system to further reduce pollutants.

Soapstone's Decathlon entry, the Ideal Steel Hybrid, uses this same dual combustion to achieve emissions of a single gram per hour. As the name indicates, it was crafted from both carbon and stainless steel to keep cost low. The stove won the affordability category and made good on that promise when it went on sale to the

public last year for a base price of less than \$2,000.

It isn't just the materials that make the Ideal Steel Hybrid such a bargain. It's also Woodstock Soapstone's in-house team of veteran craftspeople—most have been there for more than a decade, the longest-tenured for 34 years—who spend days waterjet-cutting, lasering, welding, and assembling the components of each 620-pound stove. The company is so confident in its work that it offers a six-month money-back guarantee, amounting to a winter-long free trial.

This winter couldn't be a better time to take them up on it. In May the EPA finally updated regulations on new woodstoves: a phased reduction to 2 grams per hour by 2020. The move provoked a lawsuit from a group called the Hearth, Patio & Barbecue Association (who knew?), and has left many manufacturers scrambling. Not the folks at Woodstock Soapstone. Says longtime manager Lorin Day: "If you look at what the standards are even at their strictest, all of our stoves that we've built since the 1990s have met those." —*Sean Manning*

HOW HYBRID COMBUSTION WORKS

A. AIR-CONTROL DAMPER

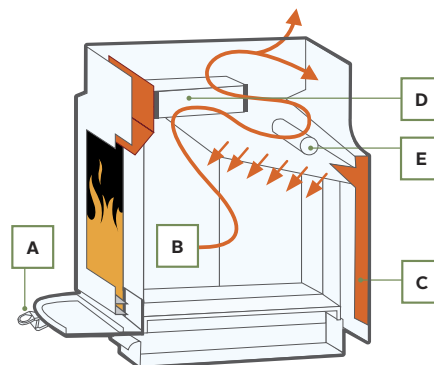
The damper, which can be adjusted in small increments, controls both the primary and secondary air vents. The more air, the more heat—but also the quicker the burn time.

B. EXHAUST PATH

The wood's primary combustion releases unburned gases and particles that waft up and across the fireback—sloped for a better view of the secondary flames.

C. PREHEATED SECONDARY AIR

Secondary air is heated as it travels up a channel along the back of the stove. Passing through a secondary combustion chamber, it meets and ignites the unburned gases and particles at the fireback.



D. CATALYTIC COMBUSTOR

Remaining gases and particles are filtered through the catalytic combustor, where they are sparked and burned off by precious metals coating the honeycomb-shaped, stainless-steel foil.

E. PREHEATED CATALYST AIR

On a high burn, secondary combustion would normally consume most air, rendering the catalytic combustor less effective. But a self-adjusting perforated tube continues feeding preheated air to the catalytic combustor.

“NO!



NO!

NO!

**THEY DON'T MEAN
THE SHUTTLE!**

**THEY DON'T
MEAN**

THE SHUTTLE!”

An oral history of the space shuttle *Challenger* disaster.

By MARGARET LAZARUS DEAN



January 28, 1986, 11:39 a.m., Cape Canaveral, Florida.

IT WAS SUPPOSED TO BE ONE OF THE GREATEST ACHIEVEMENTS IN THE HISTORY OF THE UNITED STATES SPACE PROGRAM.

A civilian—a schoolteacher, an emissary of the hope for tomorrow—was going to space. Christa McAuliffe, a thirty-seven-year-old mother of two from Concord, New Hampshire, had been selected from eleven thousand entrants to NASA's Teacher in Space contest. She became a symbol of optimism and progress amid Cold War tension. And the rest of the shuttle crew was itself a representation of the strength of American society: Gregory Jarvis, Ronald McNair, Ellison Onizuka, Judith Resnik, Michael Smith, and Commander Dick Scobee. Two women, one of them Jewish. An African-American. An Asian-American. They were the most diverse group of astronauts NASA ever assembled.

On the morning of January 28, 1986, despite concerns within NASA and among others working on the launch that the weather was too cold, the shuttle *Challenger* blasted off. Seventy-three seconds later, it broke apart in long, grotesque fingers of white smoke in the sky above Cape Canaveral, Florida.

The shuttle program was retired in 2011. But the sacrifice of the seven astronauts who perished that day should never be forgotten. To mark the thirtieth anniversary of the tragedy, *Popular Mechanics* found and interviewed more than two dozen people who were closely involved in the launch and its aftermath. Our interviews uncovered new details about not only the catastrophe but also the investigation that followed. Many of these people have never met, but they are linked by that day—bound by horror and loss as well as by endurance and hope. Never before have so many voices of this unfortunate fellowship been collected in one place. Their memories accumulate to tell the remarkable story of one terrible day, its painful aftermath, and its hopeful legacy.

I. "NICE AND CLEAR"

Originally scheduled for January 22, the launch of *Challenger* was delayed or scrubbed five times in six days due to weather and mechanical issues. Another attempt was scheduled for Tuesday morning, January 28. The night before, the temperature dropped into the 20s.



STEVE NESBITT (NASA public affairs officer working at Mission Control): There had been a couple of scrubs in the days before. That was not unusual. Some of the most conservative people you will ever find are in Mission Control. If something wasn't right, they were quite willing to delay and come back another day. But that mission just went on and on. A friend of mine had been scheduled to do it, but he was so tired. So I said, "Let me take your shift for you. I'll do the launch of *Challenger*."



BOB HOHLER (journalist for Christa McAuliffe's hometown newspaper, *The Concord Monitor*): I remember Christa's parents being frustrated and they told me she was getting frustrated too. It's hard just to keep going through the launch-day preparations. That's a big production.



JOHNNY CORLEW (member of the closeout crew, which secured the astronauts in the spacecraft and sealed the hatch): I was on every one of the attempts. I didn't get tired of it. It was an honor to be able to work with the astronauts.



CARL MCNAIR (brother of Ronald McNair): Monday night Ron called me and said that because of the icy conditions it didn't look like they were going to launch. My wife was pregnant with our daughter, and she really didn't need to be hanging around for an indefinite period of time. So we came back to Atlanta. My mother and aunt and Ron's wife stayed down there. I regret that to this day.



JOHN ZARRELLA (CNN correspondent): On Monday night a cold front was coming into Florida, so the network decided to send me out into the orange fields to cover the freeze. We were out there all night, then ran back over to the Kennedy Space Center. We thought we'd cover the launch, go back to the hotel, go to sleep, then head back home. That morning was bitter cold.



HOHLER: I remember driving in to the Space Center on this sort of eerie dark morning, this sort of pearly sky. I'd never seen a launch before, so I didn't understand as well as I do in hindsight how cold it was.



NESBITT: I do remember feeling unsure whether we would be going on that particular day because it was quite cold. I remember seeing the video from the Kennedy Space Center of ice teams looking at icicles hanging off the spacecraft.



JOHN TRIBE (chief engineer for Boeing/Rockwell Launch Support Services): I described it as the ice-house scene from *Dr. Zhivago*. I said, "There's no way we're going to fly."



CORLEW: When we brought the astronauts out there, we reminded them to use the potty on the Astrovan because the one at the 195-foot level was frozen. I told [Commander] Dick Scobee, "It's pretty cold to be flying today." And he said, "No, it's great weather to be flying in. Nice and clear."



ZARRELLA: There wasn't a cloud in the sky. You could cut that sky with a knife. It almost looked like the sky was frozen. At eleven o'clock, everybody went down from the press mound over this grassy field, out to where the countdown clock was.

Challenger was the second of fifteen planned shuttle launches in 1986—six more than the year before. Launches had become so routine that none of the three network television stations broadcast *Challenger* live—only CNN and a few local stations. However, NASA set up a special feed to McAuliffe's school and hundreds more around the country so kids could watch from their classrooms.



MEGAN RAYMOND (Concord High School student): I remember realizing the whole country was going to be watching this launch, and that we were going to be at the epicenter of that. I was sitting in the cafeteria, and there were tons of media—zoom lenses right in your face, microphones right in your face. They wanted to get a moment-to-moment reaction.



KENT SHOCKNEK (anchor for Los Angeles NBC affiliate KNBC): Our station had committed to covering the launches and landings when other stations weren't. We went in that morning with a very small crew. We didn't use our main news set—that would have been too expensive just for a five-minute broadcast. We used this tiny, shoebox studio with a locked-down camera, no cameraman. We used the NASA feed and I would just narrate over it. I had a big three-ring reference binder on the shuttle program that I would take into the studio with each launch. So I went in with my binder and a glass of water

and I got ready to do what I always did—to interpret what was going on.



DAN RATHER (CBS Evening News anchor): I was seated in what we call the fishbowl, the small glass room where we made decisions about what was going on the evening news. I'd been covering NASA since the early 1960s. Back when there was a plan to put journalists into space. I had dreamed of being that journalist. I'd have gone in a second.



RHEA SEDDON (astronaut): I happened to be at an off-site building [near Johnson Space Center in Houston], doing some training for my next mission. The launch was supposed to start around the same time as our meeting, so we found a TV and turned it on. It's always a joyful morning, especially to see friends go to space.



CORLEW: We made sure they were all properly suited before they went into the shuttle, made sure everything was right, made sure the hatch was closed properly. The whole crew was really jovial that morning. It was a joke between me and Christa: I'd told her I was going to bring her an apple. The day before she said, "Where's my apple?" So the day we launched, I made sure she got her apple. She handed it back and said, "Save it for me. I'll eat it when I get back."



BARBARA MORGAN (Christa McAuliffe's alternate, trained with the Challenger crew): The crew was fantastic about integrating Christa really well. Dick Scobee did a great job of helping us understand the risks. There are many ways for things to go wrong. He told us that they would more likely be people issues than equipment issues.



TRIBE: I couldn't believe they came out of the MMT [Mission Management Team] meeting with a recommendation to launch. Based on the ice alone, I thought it would be no-go. The ice was an unknown.

II. "GO AT THROTTLE UP"



JUNE SCOBEE RODGERS (wife of Dick Scobee): The families watched the launches from on top of the Launch Control Center. We had been watching the television in a room inside the building during the countdown, and we went up on top for the actual launch.



SUSAN CAPANO (Concord High School teacher): I was in a classroom that seated thirty kids, and there were maybe sixty kids in there and another eight or ten teachers. The school was just overwhelmed with excitement.



RANDY KEHRLI (staff counsel for the Presidential Commission on the Space Shuttle Challenger Accident, also called the Rogers Commission): Watching a launch [in person], your heart goes up into your throat. The ground shakes under your feet. It's just the most impressive physical experience, most impressive performance of a machine I've ever seen. And it's like, my gosh. We can do this?



ZARRELLA: Astronauts have told me over the years that the space shuttle is clearly the most complicated vehicle ever built. There's no

the left. I typically did not watch that, because once the launch occurred I was just going crazy trying to gather all the data, jumping back and forth between places on the data screens so I could pick information up.



DICK COVEY (astronaut who, as capsule communicator, or capcom, for Challenger, was the sole voice of communication to the crew from Mission Control): We had been disciplined to watch our data, not to get distracted by watching whatever video might be running in the control center. So I'm watching my data, and there's nothing unusual through the throttle up. The engine guys confirm that the engines look good, so I make a call: "Go at throttle up." Dick [Scobee] responded. And then I'm starting to think about what's the next thing that's coming, if we're going to make a call or whatever, and the data just went all M's, which is "missing."



NESBITT: I heard the capcom say, "Go at throttle up," and then Dick Scobee came back and said, "Roger, go at throttle up." And right then you hear the crackling in the audio. I heard the crackling—but we were always losing communication and picking it up again.



The Challenger crew on its way to launchpad 39B at Kennedy Space Center.

III. "EVERYBODY SHUT UP. SOMETHING'S WRONG."



BRIAN PERRY (NASA flight dynamics officer): The first indication that we got of any kind of trouble was when I got a call from one of our backroom folks who's in charge of processing the radar coming in. We have at least three different radars tracking the vehicle at any time, and they all have to provide a consistent indicator of where the shuttle is. She reported that the filter [the software] had disagreeing sources, which is not normal but not necessarily unheard of. You can get birds and airplanes and stuff in the way. So that by itself didn't necessarily concern me.



COVEY: Fred [astronaut Fred Gregory] was in charge of weather and so he was able to watch the video, and he almost immediately says, "Look!" And so I turned and I looked, but I didn't know what I was looking at. I didn't see how it originated, nor did I understand exactly what it was. It just didn't register with me.



NESBITT: Sitting to my left was a Navy flight surgeon. She was able to watch the TV screens, and as I was speaking I heard her say,

doubt about that. Fly off like a rocket, go into space, service the Hubble Space Telescope, grab onto satellites, fix them in the cargo bay, throw them back into orbit, build an International Space Station. And then when the job is done, land back on Earth on a runway. We're never going to see that again in our lifetimes.



MCNAIR: After Ron made his first trip to space [in 1984], he came over to my house with this video of it, and he said, "Let's check this out." We connected it to my speakers—I had these big four-foot speakers. Those things were just woofing. He just wanted to watch the actual launch part over and over again, the first minute, just the roar of the space shuttle. It finally blew out my speakers.



NESBITT: I had two screens in front of me that I could use to call up a variety of data, like the engine performance, velocity, altitude, downrange—all the flight parameters. And there was a color television set farther off to

"What was that?" I paused for a minute and looked over, and I saw the two SRBs [solid rocket boosters] veering off on wild separate rides.



SED DON: I said, "Oh, look, you can see the boosters are coming off." And one of my crewmates said—he was looking at his watch—"No, it's too early." We weren't supposed to jettison the boosters until they were burned out.



SHOCKNEK: My first thought was that perhaps an SRB had fallen off prematurely, but the size of the explosion and the asymmetry of that fireball—I knew this was not a solid rocket booster being jettisoned. I remember saying, "My God"—not something I would say in the course of any other broadcast day.



ZARRELLA: From our vantage point, we could not see the fireball from the ground.

We couldn't see it. I remember distinctly you could see the cloud of smoke and it appeared there were fireworks that were shooting out from behind the cloud. We stood there for what seemed like an eternity. We were all looking at it, watching. And looking at each other, because we all knew something was wrong.



CAPANO: The kids in the classroom were shouting and cheering as it launched. And then we started hearing things from the TV. The kids were talking, they were all excited, and we had to quiet them because we'd started hearing that something had gone wrong.



RAYMOND: I remember seeing the explosion, the two streams of white smoke, and realizing there was no shuttle in the middle. I remember thinking specifically: Wait, that doesn't look right. I remember hearing cameras clicking. I remember one of our beloved teachers standing up on the cafeteria table and shouting, "Everybody shut up. Shut the hell up. Something's wrong." We respected him so much that when he did that, we got really scared, because he was scared.



SED DON: The camera panned back, and all you could see was a cloud of... *stuff*. We thought the engines were still going with the shuttle attached to the tank. Then they showed the ocean, and there were pieces coming down—big chunks of something.



TRIBE: In the firing room [in Launch Control at the Kennedy Space Center], we could see it out the window. All I remember now

is one wing spiraling down, like a leaf coming off a tree. Of course it was plummeting down, but it looked like it was slow in real life. We were stunned.



HOHLER: I was taking pictures of Christa's parents, with my back to the launch. So I didn't see it myself. I just watched her parents' faces as it occurred. And I knew right then that life was never going to be the same.

IV. "THERE WAS A PERIOD OF SOMETHING LIKE DISBELIEF"



SCOBEE RODGERS: I couldn't hear what was being said. It wasn't clear what had happened. We came down from the roof, and we were gathered around the television. Then I was



seeing replays and I heard the words "major malfunction."



NESBITT: I kind of paused to gather my thoughts, hoping to hear something on the flight director loop. There was nothing for several seconds, and I felt an urgent need to say something, to plant a flag here that acknowledges something terrible or unusual has happened. But I didn't actually know what was going on. I didn't want to say, "The spacecraft has exploded," because I didn't know that for sure. I wanted to be correct. So I said, "Flight controllers looking very carefully at the situation. Obviously a major malfunction." Some people criticized my delivery, criticized that as being an understatement when clearly the crew had just died. But in those immediate seconds right afterward, that information was not available, and my own sense of professionalism would not let me make that kind of statement, that the crew was lost, without having that confirmed.



PERRY: After a while [the inconsistent data] went on longer than we thought reasonable, especially when we weren't getting any calls from onboard. So I asked my traj [trajectory] guy, who's talking to the range-safety people, to ask if they were seeing anything. The guy down at the range responds, "It all blew up." Traj and I look at each other, and traj says, "Say that again?" And he says, "It all blew up!" And traj says, "What did?" And he said, "The shuttle." And that was when I made the call to [flight director] Jay [Greene]: "RSO [range safety officer] reports the vehicle has exploded." That was the first that a lot of people in the room knew about it.



CAPANO: We got the kids quiet, and then I remember that the line that came across the TV was "The vehicle has exploded." One of the girls in my classroom said, "Ms. Olson [Capano's maiden name], what do they mean by 'the vehicle'?" And I looked at her and I said, "I think they mean the shuttle." And she got very upset with me. She said, "No! No! No! They don't mean the shuttle! They don't mean the shuttle!"



RAYMOND: The principal came over the PA system and said something like, "We respectfully request that the media leave the building now. Now." Some of the press left, but some of them took off into the school. They started running into the halls to get pictures, to get sound—people were crying, people were running. It was chaos.

Some students started chasing after journalists to physically get them out of the school.



RATHER: I remember seeing it on the monitor. There was a period of something like disbelief. There wasn't any question I had seen what I'd just seen, but it was such a shock. I remember the plume of smoke. It was eerie—the plume of smoke formed a fork, like a wishbone. I remember saying some version of, "God almighty, this thing has just blown up." I ran to the studio, went live on the air. The maximum test of anchoring is major network television coverage of a disaster. Because you're operating without a script. In one ear, I had the director of the program giving me directions—for example, "Go to this correspondent." In the other, I had researchers giving me a constant flow of suggestions, checking and double-checking facts. It's a constant ad-lib situation. From the moment it happened, I knew we'd be on the air until late at night, and indeed we were.



JEAN BECKER (*USA Today reporter*): I was in the newsroom that day, in Washington, D.C. I can see myself sitting at this big round desk. About half of the newsroom was watching it. There was just this eerie silence, and then a sense that we had to get to work covering this. I can still see the main editor coming out of her office and barking, "Jean! You're on your way to the airport right now. Get your purse, you're gone." I didn't go home. I didn't pack. I didn't even have a toothbrush. I just got on the plane and went down there.



ZARRELLA: I was running up to the press dome to find out from the NASA public affairs people what was going on. My cameraman was on an elevated mound, and as I ran up, he had his head up to the eyepiece and his camera trained on the cloud. And I'll never forget: I said, "Steve, what happened?" And he looked away from his eyepiece and he said, "The f—ing thing blew up." Those were his exact words. I headed right up into the press dome, and when I got there it was already bedlam.



JAKE GARN (*U.S. senator and crew member on a 1985 shuttle mission*): I was watching from the main visitors' area. I had flown myself just six months before. I knew this crew personally. We didn't train for the same flight, but we were in training at the same time. Just after the explosion, it was just hugs and tears. Just sort of disbelief. Is this really happening? The mind doesn't function too well when you go through a tragedy like that.

V. "MR. PRESIDENT, THE CHALLENGER EXPLODED"



KATHY OSBORNE (*executive assistant to President Reagan*): I received a phone call from White House staff people who saw it on TV in another room. The president was in the Oval Office with his White House senior staff. They were having a meeting about the State of the Union speech, which he was supposed to deliver that night.

There were two ways to come in to the Oval Office. People could come through the Roosevelt Room, which is a prettier way to enter, so we brought outsiders through that way. Or they could come through my office, which is what staff always did. Nobody walked into the Oval Office unless they saw [executive assistant] James Kuhn and myself first, because they didn't know what was going on in the office and we did. When I got that phone call, I hung up and, rather than just going right into the Oval, I felt like I needed to turn on the TV. I was horrified by what I was seeing replayed over and over on

the screen. After a couple of minutes, I went into the Oval Office and the president was in the process of talking. I was standing there with the door open, holding it open and just waiting a few seconds for him to finish his sentence. [Press secretary] Larry Speakes was on a couch facing me, and he could see by the look on my face that something was wrong, and he stood up. And just as I started to say, "Mr. President," Pat Buchanan almost knocked me over trying to get through the door to the Oval Office and shouted something like, "The *Challenger* exploded."



JAMES KUHN (*executive assistant to President Reagan*): Pat Buchanan came tearing down into [Kathy Osborne's and my] little reception area and said, "The space shuttle just blew up." He went right into the Oval Office and told the president. We were all so stunned. It was just complete silence.



PAT BUCHANAN (*White House communications director*): Reagan looked at me with this look on his face, and said, "Isn't that the one with the teacher on it?" And I said, "Yes, sir."



OSBORNE: The president's immediate reaction was, of course, a look of anguish. We moved him and most of the senior staff into the president's backup office where the television was. They were back there quite a while, just watching it replay constantly.

VI. "MAGICAL THINKING—THE HOPE THAT THEY COULD HAVE SURVIVED"

Live TV images offered a glimmer of optimism: the sight of a parachute descending. But it was only the shuttle nose cap. At first, the prevailing story was that the crew had been killed instantly. However, later investigations revealed that the cabin had been severed from the shuttle and projected free of the fireball, and that the crew had briefly survived. Despite plummeting at more than two hundred miles per hour, the cabin would take almost three minutes to reach the ocean. Only after six weeks of searching were their bodies recovered.



PAT SMITH (*brother of Michael Smith*): I was down in Florida for some of the launch attempts. I left and headed home to North Carolina. I was still on the road, coming home with my wife and children, just ten minutes from home, and I said, "It's time for the launch. Let's see if we can find anything on the radio." We didn't have to turn the dial very far to find out

what had happened. Everybody was talking about it. My wife asked, "Do you think they got out?" I said, "There's no way they got out."



HOHLER: I had this sort of magical thinking—the hope that they could have survived.



COVEY: At best, the orbiter was separated from everything else and maybe trying to find a way to fly. And the worst thing in an emergency when you are flying is to have someone on the ground trying to talk to you without giving you the help that you need. So I was reluctant to be a distraction unless I had something I could tell them. If they weren't talking to us, then they either didn't have the ability to talk to us, or they were busy enough that they didn't want to talk to us. I asked for emergency procedures, contingency aborts, anything that we could do to help them. And then it became obvious that there wasn't anything we could do, and we were spectators in a tragedy.



SCOBEE RODGERS: I knew they had been trained to return to Earth some way, that there were different places they could return to. But when we were standing by the elevator to go up to the crew quarters, the radio was on and we heard, "Everyone lost. No crew members survived. All are lost." I heard that.



MCNAIR: We'd traveled all night getting back to Atlanta, and when I got up I turned on the TV. I saw the shuttle launch, and when I saw that awkward veering of the solid rocket boosters I immediately knew something was wrong. I knew then and there we had lost Ron and all the other astronauts. My wife saw me just shattered, weeping, and she said, "What happened?" When my dad finally got up, I told him, "Dad, you have to see this." Not until that day, and never after that day, had I seen my dad cry. I can feel it now, that feeling.



RAYMOND: I just remember walking the hallways and seeing faculty members sitting by themselves in an empty classroom at a desk, just in total shock. I remember a student who had been really close to Christa, and he was just pounding a locker door over and over again with his fist.



SHOCKNEK: My obligation was to be as composed as possible for viewers, but I was shaken up. It's pretty obvious if you look at the video after we lost our signal and the director punched up the camera on me in the studio that I had to take a big swallow and try to come up with airworthy information. With everything that was going through my mind, the one thing that didn't—until I was off the air and slumped back in my chair—was the realization that I knew two of the astronauts.

Over the years I had a couple times run into El Onizuka and Judy Resnik. I remember how friendly they both were. To not even realize until later that I knew two of those folks struck me as a reminder of what an amazing thing the mind is—pushing things forward that are needed right at the moment and burying away those that are not.



SCOBEE RODGERS: We were standing there in the crew quarters in a circle, the families, when Vice President Bush, Senator John Glenn, and Senator Jake Garn came to us, these people grieving. I looked at everybody, waiting for someone to say something. No one spoke up. So I thanked them for coming. And I said that our loved ones valued their mission and the value and importance of spaceflight. And that to a person, I think we all would agree, spaceflight should continue.



GEORGE H.W. BUSH (*vice president*): While I was meeting with the families, June Scobee Rodgers looked me in the eye and begged me not to let what had happened to her husband and the *Challenger* end space exploration.



GARN: I had some feeling for what the families were going through because I lost my first wife in an automobile accident. It's difficult when a friend dies, but to lose a whole group at once...

VII. "HE KNEW HE WAS SPEAKING TO THE CHILDREN OF AMERICA"



BUCHANAN: We called in Peggy Noonan, told her what we needed was a short speech for the president to talk about what had happened. She must have written it in an hour and a half.



PEGGY NOONAN (*speechwriter and special assistant for President Reagan*): If you worked for Ronald Reagan, you knew what Ronald Reagan thought. He knew he was speaking to the children of America, but he also knew at the same time he was speaking to the adults of America. And he was speaking to the world at a time of Cold War tension. He knew those opposed to us would see this as a military setback. So he had to speak to everybody, and not patronize anybody. And of course, because he was Reagan, he could.

The State of the Union was postponed, and President Reagan delivered a nationally televised address from the Oval Office at 5:00 p.m. Just four minutes long, it is considered one of

the greatest speeches by a sitting American president and included the invocation of a sonnet by early twentieth-century British-American poet and aviator John Gillespie Magee, Jr. "We will never forget them," Reagan said, "nor the last time we saw them, this morning, as they prepared for their journey and waved goodbye and slipped the surly bonds of Earth to touch the face of God."



KUHN: I was right there in the Oval Office with him while he was giving that address. Reagan was a tower of strength that day and going forward. He was always steady in the worst of times and steady in the best of times.



NOONAN: It didn't seem that the president was satisfied with the speech. He seemed even sadder when it was over than he was before. I think we all went home feeling maybe that didn't work. But he called me the next day. He told me that he hadn't thought that it worked, but now he did.



OSBORNE: The president was asking the staff for more details, like how could this happen, where were the astronauts' families, what could he do to help them. The president said he wanted to call the individual families, but he wanted to wait until the following day rather than imposing on their grief and their privacy that same day.



KUHN: Part of my job was to make a decision about what calls to put through to the president. I got a call from the president's operator late that night, and she said, "I have Christa McAuliffe's father-in-law on the line, and he wants to speak to the president." And I thought, Oh, boy. This is going to be difficult. I was on the phone with him for about forty-five minutes. His anguish was unbelievable. He said it was President Reagan's fault that *Challenger* had exploded, and he wanted to know what President Reagan was going to do to make it right. I let him do 90 percent of the talking, and I tried to tell him as much as I could about how anguished the president was. At the end, I told him, "You will hear back from us." I put him in touch with the crisis communications center at the Kennedy Space Center. I talked to a person I knew down there, and she said, "Jim, this is our job. Let us handle it from here."

VIII. "THIS ISN'T GOING TO BE ANOTHER WARREN COMMISSION"

Less than a week later, on February 3, President Reagan ordered a special investigation of the accident.

Headed by former secretary of state William Rogers, the Rogers Commission included Neil Armstrong, Sally Ride, Chuck Yeager, Nobel Prize-winning physicist Richard Feynman, and other experts in aeronautics, aviation, and disaster analysis. Their final report would be a stinging rebuke of NASA and would lead to a two-and-a-half-year suspension of the shuttle program.



COVEY: People said, "Well, the external tank obviously exploded," because that was what made the big fireball. But what caused it, nobody had a clue. It was days if not a week before any of us could say, "All right, now I'm starting to understand what went wrong."



TRIBE: I was working for North American Aviation at the time of the Apollo 1 fire [in 1967, which killed three astronauts]. We built the Apollo capsule. I was on station that night, and the last test we performed before the fire was Gus Grissom and me working through a static fire simulation. The comm system was bad, and we took a ten-minute break to try to clear it up. It was during that ten-minute hold that the fire broke out. There are a lot of differences and a lot of years between these two disasters, but some of the drivers are the same. The Apollo fire was driven by trying to go too fast. The hardware and the procedures weren't ready. And of course, *Challenger* was also pushing too hard to meet schedule pressure: launch fever. In our business, it's when you don't do things in a carefully conducted manner that you start to get into trouble.



DONALD KUTYNA (*Air Force general and Rogers Commission member*): Bill Rogers was the smartest guy in Washington on how to handle politicians. His main function was to keep the damn politicians—all of whom wanted to get their names in the paper by doing something about the *Challenger* accident—at bay.



KEHRLI: The first thing Rogers said to everybody was "This isn't going to be another Warren Commission. We want to find the answer, the true answer, and we need to do it the right way." We were extremely sensitive to the fact that we would be accused of whitewashing, trying to get NASA off the hook. And we were sensitive to the charge that there was pressure by the White House—we investigated the possibility of White House pressure as a possible cause. I think that was the genius of Rogers and the people who came up with the commission members. There was a wide variety. It wasn't all military. It wasn't all NASA. This was a very hardworking commission. Rogers was there every day. Sally Ride was

there every day. Neil Armstrong was there every day. You have to remember at the time how the nation felt about it. *How could NASA let us down? They're heroes! They went to the moon! How could these seven people be dead?* It was bringing America to its knees. And so for six months we worked seven days a week, twelve hours a day.



CHUCK YEAGER (*Air Force general and test pilot*): Finally they were getting some military Air Force guys on it. I was surprised to be included. I had to think about whether or not to participate. I knew that NASA was screwing up.



ALTON KEEL (*engineer; executive director of the Rogers Commission*): It took almost every waking moment. I took off only half a day in the entire six months. At first, the commission was serving as oversight of NASA investigating itself. The first hearing was a closed-door hearing, just commission members and the witnesses, who were from NASA and Morton Thiokol [the contractor that had built the solid rocket boosters]. The intent of the meeting was for NASA to tell us typically what happens during launch—not specifically *this* launch but generally how it was supposed to go. Finally, Allan McDonald from Morton Thiokol, who was project manager for the solid rocket motor, said, “Mr. Chairman, may I say something?” He was quivering in his chair. Rogers said, “Of course.” McDonald said, “We recommended *not* to launch.”

And then you could have heard a pin drop in the room. Everybody went quiet. Then everything started to unfold from that point.



KUTYANA: On STS-51C, which flew a year before, it was 53 degrees [at launch, then the coldest temperature recorded during a shuttle launch] and they completely burned through the first O-ring and charred the second one. One day [early in the investigation] Sally Ride and I were walking together. She was on my right side and was looking straight ahead. She opened up her notebook and with her left hand, still looking straight ahead, gave me a piece of paper. Didn't say a single word. I look at the piece of paper. It's a NASA document. It's got two columns on it. The first column is temperature, the second column is resiliency of O-rings as a function of temperature. It shows that they get stiff when it gets cold. Sally and I were really good buddies. She figured she could trust me to give me that piece of paper and not implicate her or the people at NASA who gave it

to her, because they could all get fired.



KEHRLI: The engineers from Morton Thiokol had raised holy hell the night before the launch. And they were right. This concern about the joint sealing was not new. They had been working this problem for years, and they hadn't fixed it yet. Engineers were saying, “You can't fly in these conditions.” But then NASA kept waiving the launch constraint from flight to flight. It's like Richard Feynman said, “That's like playing Russian roulette. Sooner or later it was going to get you.” And that's exactly what happened.



KUTYANA: I wondered how I could introduce this information Sally had given me. So I had Feynman at my house for dinner. I have a 1973 Opel GT, a really cute car. We went out to the garage, and I'm bragging about the car, but



Reagan watches news coverage of the disaster with his staff, including James Kuhn (second from left) and Pat Buchanan (second from right).

he could care less about cars. I had taken the carburetor out. And Feynman said, “What's this?” And I said, “Oh, just a carburetor. I'm cleaning it.” Then I said, “Professor, these carburetors have O-rings in them. And when it gets cold, they leak. Do you suppose that has anything to do with our situation?” He did not say a word. We finished the night, and the next Tuesday, at the first public meeting, is when he did his O-ring demonstration.

We were sitting in three rows, and there was a section of the shuttle joint, about an inch across, that showed the tang and clevis [the two parts of the joint meant to be sealed by the O-ring]. We passed this section around from person to person. It hit our row and I gave it to Feynman, expecting him to pass it on. But he put it down. He pulled out pliers and a screwdriver and pulled out the section of O-ring from this joint. He put a C-clamp on it and put it in his glass of ice water. So now I know what he's going to do. It sat there for a while, and now the discussion had moved on from technical

stuff into financial things. I saw Feynman's arm going out to press the button on his microphone. I grabbed his arm and said, “Not now.” Pretty soon his arm started going out again, and I said, “Not now!” We got to a point where it was starting to get technical again, and I said, “Now.” He pushed the button and started the demonstration. He took the C-clamp off and showed the thing does not bounce back when it's cold. And he said the now-famous words, “I believe that has some significance for our problem.” That night it was all over television and the next morning in the *Washington Post* and *New York Times*. The experiment was fantastic—the American public had short attention spans and they didn't understand technology, but they could understand a simple thing like rubber getting hard.

I never talked with Sally about it later. We both knew what had happened and why it had happened, but we never discussed it. I kept it a secret that she had given me that piece of paper until she died [in 2012].



KEEL: We recorded every single document that came in and out, every phone call, every piece of correspondence. No matter how obscure or how fanciful the charge, we investigated it. We got people saying aliens did it—we had an investigator go out and talk to that person. We wanted the report to be a narrative and not just technical information—to tell a story, to have an effect. The only person who hung around while it was being edited who didn't have to be there was Neil [Armstrong]. He would have a nip of single-malt scotch and regale us with stories about landing on the moon with Buzz Aldrin, looking for a place to land while the fuel was running out. If you ask me in hindsight would I do anything differently—at the risk of seeming immodest, the commission got it right.



KEHRLI: I do not think it was a cold, intentional calculation on NASA's part. I think it was a flaw in the decision-making structure of NASA. I think there were some incorrect judgments, but they were judgments. It might have been negligence. It probably *was* negligence. But in terms of criminal, cold, calculated intent, I don't think there was any of that.



COVEY: It was disappointing, angering almost, to find out that discussions had been held relative to [the known issue of joint failure in solid rocket boosters]. Why wasn't that a bigger issue? How did we get to the point of accepting that indicator of a system not

working the way it was designed? Why had we been willing to accept that?



RATHER: The media were enthralled with the space program, including this reporter. We didn't ask enough questions. When it became clear that the morning was going to be cold, an alert and deep-digging media would have figured out that it's more dangerous. That should have been a bigger caution flag. Frankly, in the end I don't think it would have made a difference. The decision-makers at NASA were hell-bent to launch that morning. NASA's argument was that when you go to frontiers that are so dangerous, nobody should be surprised when disasters happen and we just need to accept that as inevitable. I questioned that at the time, and as the years have gone by I still question it.



SMITH: What really bothered me is that they knew there was a chance it was going to happen. That is awful. That is unbelievable. When those people knew they were putting those seven people on that space shuttle with a chance of them dying, I have a real problem with that. I have a problem with anybody who plays with other people's lives.



KEEL: Part of the mistake we made and that NASA made was starting to think of the shuttle as a cargo plane while it was really still an experimental program. The probability of failure was 1 percent. If you applied that to commercial flight, that's thousands of crashes a day. We began to think of it as too routine.



YEAGER: NASA wanted the publicity for the launch. The launch had been scrapped several days in a row and the media was leaving. So they ordered the launch. They got their publicity, all right.



TRIBE: I haven't forgiven the guys that overrode the O-ring decision.

IX. "NIGHTMARES"

In addition to the suspension of the shuttle program, NASA would undergo a significant overhaul, including sweeping personnel changes and a new management structure, while both the government and contractor Morton Thiokol would pay millions in settlements to the astronauts' families. But none of that would lessen the trauma and grief.



BUSH: At age ninety-one, my memory is not what it used to be. I am beginning to think I have now forgotten more than I ever knew to begin with. But like all Americans who are of a certain age, I remember the day the *Challenger* blew up.



NESBITT: I ended up being the last person to leave Mission Control that day. My emotional feeling at the time was like a house dropped on me, and I have sort of felt it ever since. For many years I thought of it practically every day. I've often seen the picture of Christa McAuliffe's parents with the look of shock on their faces. And I've wondered if my voice or what I said contributed to their grief. Did I sound too cold in my delivery? Obviously that kind of thing haunts you.



BECKER: I finished writing my piece around midnight that night. I was pushing deadline. And I remember going outside and seeing the launchpad just bathed in floodlights. And I remember just sitting down and crying.



KUHN: A few days later, we went to Houston, to the Johnson Space Center, for the memorial service. There were fifteen thousand people there. The Reagans met with the families privately ahead of time. The president let them talk. There were twenty-five or so family members in there, and he went to each one individually, told them how sorry he was and then he let them talk to him. He listened. The family members were strong that day.



KATHIE SCOBEE FULGHAM (*Dick Scobee's daughter, who was twenty-two at the time*): I'd never even lost a grandparent. I had no idea what death meant. I did not believe it. I

was having nightmares about him being stuck on a piece of space shuttle floating around in the ocean.



RATHER: This event set a precedent for coverage going forward in which the video was so spectacular, so tragedy-laden, that we repeated it over and over again. It's at the point where now—and I include myself in this criticism—it tends to be overdone.



RAYMOND: I remember the media wanting to capture this mourning community and students in pain. People just want to see that. It's like having to stop and look at a car wreck. I remember the windows of the first-floor classrooms had to be covered with paper, because a few journalists were standing on each others' shoulders and holding cameras through the windows just to get pictures. But it was really incredible how much the school and the community came together. Students would stop and check on faculty throughout the day. Just pop your head into a classroom and check on a teacher and say, "How are you doing?" All those hierarchies melted away. It lasted a very long time.



SCOBEE RODGERS: After we were back home we could not turn our TV on without seeing it. We'd go to the grocery store and see the front page of newspapers, magazines—everything was a reminder. I'll never forget the first time I went to the grocery store. In my mind I wasn't a widow yet. I was still Dick Scobee's wife. He loved peanut butter, and I went over and picked up a jar of peanut butter like I always did. And I sat down in the store and cried, because I didn't have anyone to take that peanut butter home to. There's not a day that goes by that I don't think about him.



SCOBEE FULGHAM: When grief is public, I think it's so much worse. Grief is very complicated—there is nothing simple about it. It is not a straight line. Sometimes it's okay, and sometimes, even now, there will be days when I really miss him. Or there's something that the kids have done that I really wanted him to see, and I'll just think, I really wish he was here. He loved Christmas. Christmases always make me miss him.



SEDDON: I think there were a few astronauts who left the program because their families worried about them. I think if my kids were really traumatized by it, my decision might have been different. But at the time my kids

took it as a regular part of life. Hoot [Seddon's husband, Robert "Hoot" Gibson, was also an astronaut] and I were committed to this life and these risks, and we were ready to go forward. We wanted to continue flying.



CORLEW: That night I went home, I told my wife, "I don't want to talk to nobody." I went back to work the next day and I told my boss, "Put me on annual leave." I went to Lake Okeechobee and fished for three weeks. I couldn't do it anymore after *Challenger*. They asked me if I wanted to be on the closeout crew, and I said, "No." I wouldn't even watch a launch until after "Go at throttle up." Only then I would turn and look at it.

X. "WE LEARN FROM OUR MISTAKES AND TRAGEDIES"

In September 1988, the shuttle program resumed, carrying out eighty-seven missions without incident. That streak ended in 2003, when the shuttle *Columbia* disintegrated upon reentry, killing all seven crew members. Noting that "the causes of the institutional failure responsible for *Challenger* have not been fixed," the *Columbia* Accident Investigation Board recommended the shuttle be allowed to fly until the International Space Station was complete, then be either recertified or retired. In 2011, NASA sent up a shuttle for the last time. Yet the *Challenger* legacy continues to foster interest in space exploration, science, and engineering among new generations.



NESBITT: It was two and a half years after *Challenger* when we launched again. I asked my boss if I could do the launch commentary because I felt like I had an incomplete job that I needed to do. For that mission and every one after that, I always had my fingers crossed for that first two minutes and five seconds until the solid rocket boosters separate. Even though there were plenty of other bad things that could happen, once the SRBs separated and the main engines were going, I felt a lot better.



KEHRLI: I was there for that return-to-flight launch. NASA flew me down to see it. Yeah, I was scared. I remember going, "Come on, Rick,

[Commander Rick Hauck]! Come on, Rick, fly this thing! Fly it, fly it!"



MORGAN: NASA had scheduled appearances for Christa and me, for after she returned from the flight. We were to share our experiences with people all over the country. After the accident, NASA asked if I would carry on and serve in Christa's shoes as Teacher in Space designee. I thought it was important for kids to see how adults should respond to terrible situations.



YEAGER: My last job in the Air Force was as director of safety. When I got there, the policy regarding the approach to investigating accidents was finding a primary cause and secondary causes. I went to General [Michael E.] Ryan, who was chief of staff of the Air Force, and told him: "They

"The legacy of the *Challenger* is the very spirit of the American people."

—GEORGE H.W. BUSH

are only correcting the primary cause and not the secondary cause." I suggested we change it to "all-cause" accident so that all the causes would be fixed. He agreed, so we did. The airline industry followed suit, which prevented many, many accidents. But NASA didn't do this. Even after *Challenger*, they did not fix them all. They knew about the issues before the *Columbia* accident and didn't fix them.



MORGAN: The families wanted something that really represented and continued the crew's mission for education. They put together the Challenger Center for Space Science Education, which to this day is still making a huge difference. Many years later, one of my astronaut classmates told me that she was in junior high at the time [of *Challenger*]. She saw Christa and was able to connect with her, and that's when she started seriously thinking about taking the path to become an astronaut. That means so much to me.



SMITH: The real legacy of *Challenger* is a positive one. The Challenger Centers that June Scobee and Jane Smith [wife of Michael Smith] and the other families started, that is a real positive thing. It gets young people interested in space. And the space program has been a huge positive. Was it worth the cost? I'd have to say yes. Although the astronauts lost their lives, I'd have to say yes.



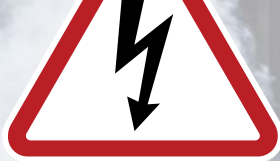
RAYMOND: I have several good friends from that time who went into education. I'm still in education. Certain things that Christa said will always stay in my head. She had a profound impact on us. She was just such a naturally gifted teacher. She could always see the statue in the stone.



MCNAIR: I think the Challenger Centers and the McNair Scholars Program are the real legacy of *Challenger*. Ron had been planning to go back to education, to teach physics at the University of South Carolina, the very same school that wouldn't accept him as a student [because it was segregated at the time]. Over sixty thousand students, either economically disadvantaged or first-generation college students, have been McNair Scholars—probably more people than Ron ever would have impacted in his lifetime. Not only those McNair Scholars, but the people they've impacted, the students they've taught.



BUSH: I believe that the legacy of the *Challenger* is the very spirit of the American people. We learn from our mistakes and our tragedies. And then we move on. And we do things bigger and better than before. *Challenger* is one of our best examples of that. The remarkable June Scobee Rodgers moved on by helping establish the Challenger Centers, which bring the joy of science and space to hundreds of thousands of our children. NASA, and our country, moved on by reaching even deeper into outer space. We have had spacecraft exploring Venus, Mars, Saturn, and Mercury. And today we have an American, Scott Kelly, commanding the International Space Station. By the time he comes home, he will have set a record for the longest time in space by a U.S. astronaut. On the day the shuttle blew up, I said, "Our fallen astronauts have taken their place in the heavens so that America can take its place in the stars." I hope the crew of the *Challenger* would feel we have honored them well. I think they would.



POPULAR MECHANICS

We've got a million ways to quantify power.

Horsepower. Ergs per second. Gigawatts.

But power is more than just numbers. Power is experience. How something feels is just as relevant as how it performs. Especially now, in this new age of automotive ingenuity. Nissan's GT-R Nismo gets 600 horsepower—out of six cylinders. The Dodge

Hellcat tearing up this page has 707 horses and can hit 204 mph. You'd have to be soulless to drive them without at least a small smile. ¶ And then there are the less quantifiable displays of power: like an extrusion press that squeezes metal like Play-Doh, or a whale with a tail that creates the thrust of a fighter jet. Ultimately, though, no matter how many hard stats and yelps of joy and amazement are involved, power is always up for debate. Powerful debate.

PHOTOGRAPH BY IAN ALLEN

PAGE 64

THE MOST

POWER



AWFUL

THINGS IN THE WORLD

THE EVERYDAY CAR WORTHY OF NASCAR



The Dodge Charger SRT Hellcat is the highest expression of America's muscle-bound past. It's a V-8, it's rear-wheel-drive, and it's certifiably huge—elements that ought to trigger nostalgia. But in its outsize ambitions, the Hellcat is something new. From the bones of a sub-\$30,000 fleet car, Chrysler builds a projectile that tops out at 204 mph. Last year Jeff Gordon qualified at pole position for the Daytona 500 with a speed of 201 mph. The Hellcat has strong brakes and decent suspension, but those components come across as afterthoughts compared with the effort that went into the engine, a supercharged 6.2-liter V-8 that makes 707 horsepower. That V-8 is the Hellcat's defining feature, all thunderous exhaust and Mad Max supercharger whine, the centerpiece of the world's most powerful internal-combustion sedan. Perhaps as a joke, or a taunt to fellow carmakers, the Hellcat comes with two keys: a red one that unleashes full power, and a black one that's ostensibly for valets and newbie drivers. With the latter key, in safety mode, the Hellcat is limited to about 500 horsepower. You know, just three Miatas' worth. Sensible.



THE SEDAN YOU CAN TAKE TO THE GROCERY STORE. OR THE TRACK.

Tesla's Model S has been around only a few years, but it has already evolved more than most cars do in a decade. It started out rear-wheel-drive and quick. Now it's got dual motors, all-wheel drive, and a Lamborghini-hounding 2.8-second zero-to-60 time. And with autopilot, it'll pretty much drive itself. We didn't really mess with that, though, because this is a car you'll want to drive for yourself. With 762 horsepower, the P90D is the most powerful sedan you can buy. And the most powerful electric car. And the most powerful American car.



5,000-MPH Bullets That Don't Need Gunpowder

The Navy's electro-magnetic railgun, which accelerates a projectile to 5,000 mph in 0.01 seconds using a simple (and enormous) charge, requires no explosives and only one man to load and fire. It's been in production since 2005 and should be completed by 2017. A few more facts:

Each projectile is 18 inches long and weighs 23 pounds.

The cost to fire a projectile is approximately \$25,000—as much as 60 times less than traditional artillery.

After storing up a charge, the gun releases 1,200 volts in 10 milliseconds.

Firing distance exceeds 100 miles.

In tests the projectiles were able to pierce three walls of reinforced concrete or six steel plates.

THE BIGGEST DAM IN THE WORLD

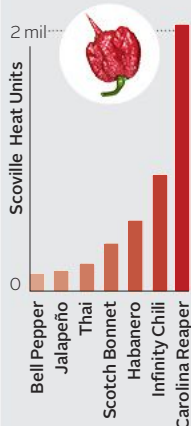


The Three Gorges Dam in Sandouping, China, is 607 feet tall and 1.4 miles wide—taller than the Washington Monument and several thousand feet longer than the Brooklyn Bridge. Its 22,500-megawatt-generating capacity is 1.5 times that of the next largest dam, producing an average of 273,790 megawatts of power each day. That's enough to run Orlando. For two weeks.



THE HOTTEST PEPPER

South Carolina's Carolina reaper pepper has a heat that's been described as "nothing but pain" and "like a white-hot ball of nickel implanted just above my stomach." Most people who try the pepper get uncontrollable hiccups. The unlucky ones throw up. The slightly more lucky ones just dry heave.



A DUMP TRUCK THE SIZE OF A TENNIS COURT



It weighs almost 800,000 pounds—and that's empty. Fully loaded, the BelAZ 75710 dump truck approaches 2 million. It's 32 feet wide and 67 feet long, which means it'd be a tight squeeze to fit on a standard tennis court (and an even tighter squeeze into tennis whites), and 26 feet tall. To power such a beast requires twin 2,300-hp diesel generators. Like its slightly smaller cousins—400-ton-capacity trucks made by Caterpillar, Bucyrus, and Liebherr—the BelAZ lives and works in giant open-pit mines.

Unfortunately, because it's made in Belarus, home to one

of the most repressive governments on the planet, it's hard to get anyone to talk about the 75710 in plain English, or even plain Belarusian. And you can't see one unless you travel to Siberia. The only user at the moment is a Russian coal company. But in a sense, every giant dump truck shares the same story: As the human population boomed in the 20th century, we demanded more and more of the world's geologic resources—coal, metals, and the rock itself. To transport these efficiently, bigger and bigger trucks were needed. The 100-ton barrier was broken in the 1950s; 200-

and 300-class trucks followed. In 1999, Caterpillar broke the 400-ton barrier with its massive 797F. The 500-ton BelAZ, like much else that came out of the Soviet bloc, is the product of an arms race.

Curiously, the BelAZ may be the last salvo in that race. One reason is economics: Mining firms are obsessive about efficiency, and improvements in reliability, durability, and performance are returning the edge to earlier, smaller trucks. Another is more practical: rubber. Nobody has found a way to make tires that can handle bigger loads. —*Tim Heffernan*

STATS

HORSEPOWER
4,600

WEIGHT (EMPTY)
400 tons

WEIGHT (LOADED)
900 tons



WHAT IT'S LIKE TO DRIVE BIGFOOT

In some ways, Bigfoot is normal. There's a gas pedal, a brake pedal, a steering wheel, a shifter for the transmission, a two-speed automatic. But there's also a rocker switch to control the rear-wheel steering, a knob to get the fuel flowing (that fuel, incidentally, is alcohol), and a toggle to start the engine, a 9.4-liter V-8 topped with a supercharger the size of a doghouse. No mufflers. Just a set of headers on each side pointing straight down and belching explosions. Push that starter and the *cough cackcackcack* rattles up through the tube frame and into your skull.

That firebomb V-8 is so loud that you upshift early because it sounds like the supercharger's going to explode. (It's bolted down with straps, in case that actually happens.) You line up the straight-away and give it half-throttle. As the hood points skyward you look down through clear panels in the floor as the truck's 66-inch tires—cribbed from a fertilizer spreader—dig in and send the 6-ton behemoth barreling down the track. You can't turn your head much, because your helmet is strapped to the seat with a HANS device that limits movement and protects you from the neck-stretching g-forces that come into play when you put 6 tons of truck into the air. Or, more specifically, return 6 tons of truck to earth.

An object this huge should not be fast. And yet, 1,730 horsepower changes the rules. The Lincoln Memorial would be fast with 1,730 horsepower. Bear that in mind as you square up for the ramp. You're supposed to goose it as the front tires hit the jump and not let up until the rear tires are airborne. Any flinch will cause the front end to dip midair and lawn-dart into the dirt. Force your right foot to stay down, feel the truck go weightless, and only then lift the pedal. It'll be a long time before you come down. Hard. —Ezra Dyer

The Second-Most-Powerful Bigfoot

Purported to have thrown a spare tire 500 feet. He's tossed 240-pound rocks and 450-pound, 50-gallon drums at people, lifted mobile homes, twisted tree trunks, and made a dog fly 40 feet after hitting it. Probably with his left hand.

THE 600-HP V-6

It wasn't that long ago that 100 horsepower per liter was considered impressive. The GT-R Nismo has 100 horsepower *per cylinder*. There are V-12s with less than 600 horsepower, but Nissan hits that number with a 3.8-liter V-6. A psycho V-6.

There's a half beat at low rpm where the Nismo might fool you into thinking it's a docile machine. Then the boost arrives and the instruments go haywire—the speedometer's counting by 20s, the tach needle stays lodged above 5,000 rpm, the traction-control icon flickers like the porch light at a \$40 motel. Six hundred horses can overwhelm a car's chassis, its ability to cope. Not so the Nismo. Its torque-vectoring all-wheel-drive system doesn't waste energy on wheelspin. Whatever's cooking under the hood, the Dunlop SP Sport Maxx GT 600 tires serve it to the pavement, no left-overs. The GT-R's sophistication and racetrack prowess somehow earned it a reputation as an aloof, robotic supercar. It's anything but. The transmission rattles and the gears gnash; the turbos huff mightily and the car does whatever it's asked. It's all-wheel-drive but it'll hang the tail out, if you're so inclined. On the engine there's a plaque signed by the guy who built it, by hand, and that guy might be named Nobumitsu Gozu because that job is done in Yokohama and not at some far-flung subsidiary. The GT-R Nismo doesn't just have 600 horsepower. It has character.

POWER MOVES

IN
INCREASING
ORDER OF
EFFECTIVENESS



A well-timed
wink

Leaving work on
time

Tipping the
maitre d'

Setting up your
chair so it's
a few inches
higher than
everyone else's

Looping in your
assistant

Tipping the
maitre d'
without anyone
noticing

The Irish
goodbye

Showing a tiny
bit of mercy

Taking the last
doughnut

Silence





KAWASAKI'S SUPERCHARGED RACE BIKE

There's a viral video that shows a Kawasaki Ninja H2 beating a Bugatti Veyron in a drag race. This is notable because the H2 is not even the quickest Ninja. That would be the H2R, a 200-mph production race bike that uses a gear-driven supercharger to help extract 300 horsepower from a 998-cc four-cylinder. The \$50,000 H2R is so indulgent, the silver paint is actually a layer of pure silver. The fact that the H2R is track only—definitely not street legal—might be the only sensible thing about it.

STATS

HORSEPOWER
300

QUARTER-MILE
About 9 seconds

PRICE
\$50,000



THE SULTAN OF JOHOR'S BOAT



We're doing 79 mph on the Sultan of Johor's new Cigarette Racing 41 GTR when Bud Lorow, Cigarette's chief test driver, says, "I think we need more prop." Lorow's right, of course, not only because he's an all-around hydrodynamic horse whisperer, but because the boat's four tachometers are pegged at 7,000 rpm, sitting on the rev limiters. Change the props, get those revs down, and then the sultan will have a nice little 80-mph fishing boat.

Wisconsin-based Mercury Racing is the reason you can buy a 41-foot outboard center-console that tops 80 mph. Other companies make big outboards—like Yamaha's 350-hp V-8—but they're big. Verado engines are narrow, built around a supercharged straight six, and every inch matters when your goal is to maximize total horsepower. Cigarette Racing also builds a 50-footer that'll take five 400-hp Verados across the stern. That's 2,000 horsepower. The 41 has a modest 11-foot beam, but that's enough real estate to hang quad Verado 400Rs.

At idle, the engines are nearly silent, offering

none of the lumpy pissed-off exhaust braggadocio of an inboard go-fast. But throttle up and it sounds like a Gulfstream G650 is attempting to land on the aft deck, the quartet of water-cooled superchargers spinning up and funneling boost to the intakes. There's still no exhaust noise—the exhaust exits underwater through the prop hubs—but the turbine-like intake symphony sounds appropriately expensive for a million-dollar boat. Cruising at 50 mph, where most center consoles are nearing terminal velocity, the Cigarette is just loafing with speed to spare. Push the throttles all the way forward and the GPS speedometer leaps to 70 mph, and then keeps climbing. You'd be breaking the speed limit on I-95 into Miami, but out here on Biscayne Bay the speed limit is unlimited, dictated by horsepower alone. The sultan, I think, will be pleased.

—E.D.

STATS

HORSEPOWER
1,600

TOP SPEED
80 mph

PRICE
\$1 million



The author, in the blue T-shirt, pushing 80 mph on Biscayne Bay in Miami.

PHOTOGRAPH BY IAN ALLEN



STATS

WEIGHT
9,000 tons

FORCE CAPACITY
16,200 tons

LENGTH
300 feet

THE MACHINE THAT SQUEEZES METAL LIKE PLAY-DOH

Universal Alloy, in the small city of Canton, Georgia, is one of the leading suppliers of structural components to companies including Boeing, Airbus, and defense manufacturers. It owes its preeminence to one extraordinary machine: a 75-year-old, 9,000-ton aluminum-extrusion press—the most powerful one in the free world.

The extrusion process is straightforward: A block of solid aluminum is pushed through a die, forming a strong, seamless structure. It's similar to squeezing toothpaste from a tube. Or like Play-Doh, but for machine parts. To make 100-foot wing struts for the A380, however, or the sockets that attach a 747's wings to its fuselage, takes a huge amount of force. Universal Alloy's machine generates 16,200 tons of pressure in order to turn 5,000-pound bathtub-sized billets of solid metal into toothpaste.

The machine is nearly 300 feet long

and is anchored to a concrete foundation 10 feet thick. Its history is just as remarkable. Built by Hydraulik in Duisburg for Germany's Luftwaffe in the late 1930s, it was brought to the U.S. in the late 1940s as war spoil, which also had the benefit of keeping the Soviets from getting their hands on it. Myths abound: that it made the skins of V-2 rockets; that the Germans sank it in the Rhine to be resurrected by the hoped-for Fourth Reich; that its base plate was used as a bridge over that river by Patton's army engineers. None of that is true, according to Paul Scaglione, the Universal Alloy engineer who oversaw the press's Canton rebuild. What is true is that it took 160 semis and seven railcars to transport the press to Georgia from its former home in Illinois. And that "all the crusty old riggers with the big beards wanted a picture with it" when the colossal job was done.

—T.H.



A Truck Powered by a Jet Engine

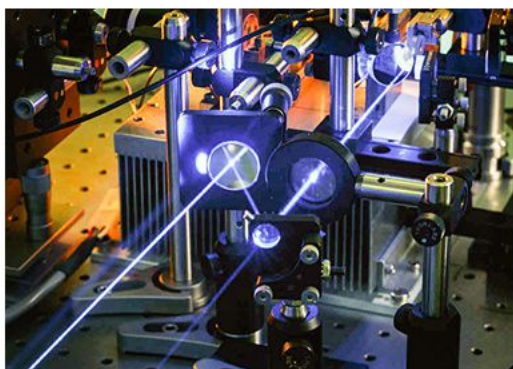
Pratt & Whitney J34-48 jet engines don't normally have afterburners. They're also not typically bolted into a Peterbilt semi. But that's the case with Shockwave, a big rig that can run the quarter-mile in 6.5 seconds with its three afterburners lit. With a total of 36,000 horsepower, Shockwave holds the record for fastest semitruck, regularly hitting 376 mph at the air shows where it performs. Good thing it also has two parachutes.



THE BEETLE THAT'S STRONGER THAN A GORILLA*

***RELATIVELY SPEAKING**

British researchers, hopefully shortly before washing their hands, discovered that male horned dung beetles, found in nearly all parts of the world except Antarctica, can pull 1,141 times their own body weight. That's like you pulling five times as much as the new F-450 (right).



The Laser That Can Melt a Car Engine. From a Mile Away.

It sounds like something that belongs on a UFO or in Putin's garage, but soon the Athena laser will be on our army vehicles. And it will be amazing. In a demo in March, the Lockheed Martin–crafted laser burned a hole through the hood and engine of a small truck. From over a mile away. The power comes from multiple lasers combined in a single beam—a setup that makes the laser more efficient and less likely to malfunction, since the failure of one of the small lasers doesn't disrupt the beam. Despite such power, Athena requires only one operator. It went into production this past fall.

THE EXTREMELY SPECIFIC CAR AWARDS

POWER
EDITION



**Most Powerful
1.0-Liter:**
Ford Fiesta
EcoBoost,
123 hp



**Most Powerful
Naturally
Aspirated
V-6:** Hyundai
Genesis Coupe
3.8-liter,
348 hp



**Most Powerful
V-6 Sedan:**
Cadillac
ATS-V, 464 hp



**Most Powerful
Three-
Cylinder:**
BMW i8, 231 hp



**Most Powerful
Two-Cylinder:**
BMW i3, 34 hp



**Most Powerful
Plug-In
Hybrid SUV:**
Volvo XC90 T8
Twin Engine,
400 hp

STATS

HORSEPOWER
More than 440

TORQUE
More than 860 lb-ft

PRICE
TBD





THE TRUCK THAT'S ALMOST AS STRONG AS A DUNG BEETLE

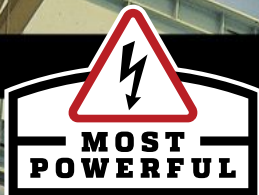


The 2016 Ford F-450 Super Duty is the most powerful pickup you can buy, with 440 horsepower and 860 lb.-ft of torque. The 2017 model will be even better.

Given the constant one-upmanship in trucks, Ford doesn't want to show its hand till the last moment, lest it get trumped by 3 horsepower—as GM did a few years back when it announced a 397-hp truck only to have Ford fire back with an even 400. What we know so far is that the new truck will be 350 pounds lighter and have a maximum tow rating higher than the current 31,200 pounds, which is enough to haul some pretty impressive items. Like these:

- 11 Bobcat S70 skid-steer loaders
- 90,000 bananas
- 5 Chevy Silverado 3500s
- A nuclear family of African elephants
- An aboveground pool filled with mercury
- The blue whale on page 75





THE SHIP ENGINE WITH MORE THAN 100,000 HORSEPOWER



The largest container ship ever built—the 1,302-foot-long *Emma Mærsk*—requires the most powerful engine in the world, the Wärtsilä-Sulzer RTA96-C diesel. A few notable details:

WEIGHT

In total, the engine weighs 2,300 tons (300 tons of that is the crankshaft).

DIMENSIONS

The engine itself is 89 feet long and 44 feet tall.

FUEL ECONOMY

With fuel consumption of 0.260 lb/hp/hour at maximum economy, it's been estimated that the engine consumes more than 39 barrels per hour and costs \$34 a minute to run.

HORSEPOWER

Its maximum horsepower is 108,920 at 102 rpm.

Despite that, it still can't get you up on water skis.





THE LEAST POWERFUL THINGS IN THE WORLD



A sick butterfly

A solar panel in the Antarctic winter

The Mitsubishi Mirage

Any cordless drill that you were hoping to use right away

Your willpower at a buffet

O'Doul's

Hurricane "Bevin"

Cell service at a football game

Jennifer Tilly's inside voice



The Strongest Mammal

Blue whales can get as long as 100 feet and weigh as much as 200 tons. A 150-ton whale can exert 120 kilonewtons of power—roughly double the thrust of an F-15 fighter jet. The force comes from massive tail muscles, but a whale's speed is due primarily to its shape. Their bodies are relatively thin, like submarines, and tapered at both ends, allowing whales to reach speeds over 20 mph. Despite this strength and speed, which protects them from natural predators, blue whales cannot break a single harpoon line from a whaling ship.



STATS

HORSEPOWER
1,200

TOP SPEED
50 mph

THE MOST POWERFUL HOVERCRAFT

The Griffon Hoverwork BHT Hovercraft can glide over mud, ice, water, and land. While carrying 18 tons of cargo. At 50 mph. To reach that speed, the hovercraft needs big fans and an even bigger skirt—the flexible cushion that traps air between the hull and the ground. Three fans fill, lift, and propel the 100-foot-long craft, which is powered by four engines from the Detroit Diesel Corporation with a maximum output of 1,200 horsepower.





Top, from left: NASA engineer Summer Wagner, medical researcher Melissa Hodges, and AT&T network engineer Samantha Sanders are three of almost three hundred current and former professional cheerleaders donating their time to the advancement of science.

SHORT SKIRTS, FULL HEADS, CAN'T LOSE

WHEN THEY'RE NOT CHEERING, A GROUP OF CURRENT AND FORMER NFL AND NBA CHEERLEADERS WORK AS SCIENTISTS, RESEARCHERS, DOCTORS, AND ENGINEERS. AND THEY ARE TEACHING THE NEXT GENERATION THAT IF THEY CAN DO IT, ANYONE CAN.



STORY ABOUT A beautiful woman always begins with a description of the flush the February wind has brought out in her cheeks. The length and litheness of her legs under the table. What she's ordered (a burger!) during the interview.

So let's try something else.

Melissa Hodges, thirty, earned a bachelor's degree in neuroscience from Vanderbilt University. No easy feat in any case, but even more impressive when you consider that at the time of her graduation, she was captain of the Vanderbilt Commodores dance team, a spirit group that performs at every football game, every basketball game, and various outreach events throughout the year.

After graduation, Hodges began working as a laboratory

technician in a Vanderbilt molecular neuroscience lab, analyzing DNA sequences in a lab coat so close in shade to her white-blond hair that they could be adjacent paint swatches on a Sherwin-Williams card. On Sundays, she marched into Nashville's Nissan Stadium in a baby-blue halter top and a skirt no larger than a dinner napkin, perfectly toned midriff bare to the admiring gaze of almost seventy thousand fans. During the times she wasn't researching the molecular components of Parkinson's disease, schizophrenia, and bipolar disorder, she rehearsed, performed, and did obscene sums of ab exercises as a professional cheerleader for the Tennessee Titans.

On a rainy Friday in Phoenix, Arizona, down the street from the furor surrounding Super Bowl XLIX, Hodges is preparing to give a presentation alongside an elite group of her peers: Summer Wagner, who holds a degree in aerospace





engineering, manages a lab at NASA's Johnson Space Center, and used to cheer for the Houston Texans; Samantha Sanders, who engineers Wi-Fi networks for AT&T and used to cheer for the Arizona Cardinals; Kelly Bennion, a Ph.D. candidate in cognitive neuroscience who currently cheers for the Patriots; and psychotherapist Brittany Bonchuk, who does the same. To be sure, all these women are beautiful. Even in the dim light of the Arizona Science Center, their eyelashes leave dark, inviting shadows on their cheeks. Their painted lips could be exotic fruits. But their appeal runs much deeper.

Along with nearly three hundred others, these women make up Science Cheerleader—a not-for-profit group of current and former National Basketball Association and National Football League cheerleaders pursuing science, technology, engineering, and mathematics (STEM) careers. They have come to the science center, braving the madhousery of Super Bowl weekend, to lead half a dozen youth cheerleading squads in a pep rally for science, to give tours of the center's galleries based on their individual areas of expertise, to sign trading cards, and to change the minds of fans who, if they've given professional cheerleaders a thought at all, probably don't imagine them teaching engineering classes when they're not on the field.

On account of the rain, the audience today is smaller than anticipated, a couple hundred people instead of the tens of thousands Science Cheerleader appearances can draw. The result is that the cheering expands to the edges of the science center's vast marble-and-concrete welcome center like helium, reverberating off the sharp-edged planes in a way that would have been lost to the damp grass and trees outside.

These days, Hodges works in the neuro-modulation division of a medical-device company, where she teaches doctors how to use electronic devices to help people with paralysis and intractable pain. She spends much of her day in an operating room. The rest she spends teaching families about therapy. In return, she receives none of the automatic flashbulb glory of NFL Sunday. Only small moments of quiet gratitude.

And yet, when she chooses to, she still attracts the attention of others like a spinning, flashing, glittering siren. "I'm Melissa, a Tennessee Titans cheerleader, and I do neuroscience," she chants, waving blue-and-silver poms. "Gooo science!"

In a semicircle around a stage, girls age nine to eleven, their Pop Warner youth-cheerleading-league coaches, and chaperones sit mesmerized. A few unsuspecting science-center visitors, perhaps in town for the game and drawn to the "Gridiron Glory" exhibit on one of the museum's upper floors, pause to watch the women perform. "Gimme an S!" the cheerleaders shout. "Gimme a C..."

"What's that spell?"

"Science!"

"What do we love?"

"Science!"



ARLENE CAVALIER is observing the pep rally from the side of the stage in a fitted tee and a navy blazer. True to the spirit of the group she has created, the erstwhile Philadelphia 76ers cheerleader dreamed up Science Cheerleader while completing a master's degree at the University of Pennsyl-

At events like the pre-Super Bowl pep rally, Science Cheerleaders cheer for STEM subjects, inspire young girls, and sign trading cards for visitors—and sometimes their brothers and dads as well.

vania. As an extension of a paper she wrote in school, Cavalier attempted to reopen a government agency that provided analysis of technology and science to members of Congress. Called the Office of Technology Assessment, it was a sort of Cliffs Notes for people who made world-changing decisions about science and technology—until it was shuttered in 1995. Cavalier hoped that reassembling the program, or something like it, could change the tone of national conversations about science policy. She wanted to get more regular people interested in the impact STEM subjects could have on their lives.

As both a researcher and a cheerleader, Cavalier, who has honey-blond hair and a forthright way of speaking, knew that scientists could often talk past themselves, boring, antagonizing, or otherwise blowing their message to a public that desperately needed to receive it. But cheerleaders! You couldn't design people more capable of catching eyes and hearts than cheerleaders. They're beautiful, sexy, athletic. They wave sparkling poms in big shining arcs. Cheerleaders are basically human advertisements for sports teams. Couldn't they do the same for stuff that matters on a national stage?

Unlike NBA and NFL stars, professional cheerleaders don't make enough money to live on, a situation that has landed several NBA and NFL teams in lawsuits over wage theft in the past year. "Throughout my tenure as a cheerleader, I held a full-time job," Hodges says. "In fact, nearly all NFL cheerleaders



have careers.” In most cases, these women are not doing menial work. They are the over-achiever types who would choose to spend twelve to twenty hours a week rehearsing and performing on top of a 9 to 5. Cavalier knew there had to be others working in STEM fields, so she contacted professional cheerleading squads, asking coaches if anyone would be qualified to join her. She found hundreds.

Perhaps now this story has progressed far enough to have earned the right to examine how these women look. Melissa Hodges, for example, has almond-shaped blue eyes and a curvy figure and white-blond hair that waves in on itself like ribbon. Brittany Bonchuk is a compact, raven-haired bombshell with obliques so defined that, were she lying down, they could hold a turn’s worth of Scrabble letters upright. These women’s sex appeal exists whether they choose to use it or not. Science Cheerleader simply provides a place where they can employ it in the service of a noble purpose.

In time, Science Cheerleader became the publicity arm of Cavalier’s other initiatives to get regular citizens more involved with STEM subjects. In particular, the cheerleaders promote SciStarter, a Kickstarteresque website where scientists can recruit regular Joes who want to participate in their experiments. At every appearance, the cheerleaders showcase a project featured on SciStarter and recruit audience members to help. In 2014, they collaborated with the University of California, Davis, on Project MERCCURI, in which they enlisted four thousand people to collect microbes to send to the International Space Station for testing. They also promote ECAST, Cavalier’s citizen-led version of the Office of Technology Assessment. Through it all, the

THE SCIENCE CHEERLEADERS PUT A HUMAN FACE ON WORK THAT CAN OTHERWISE SEEM INTIMIDATING, ANTISEPTIC, OR INACCESSIBLE. AND IT IS A VERY PRETTY FACE.

cheerleaders put a human face on work that can often seem intimidating, antiseptic, or inaccessible. It is a very pretty face.



THE WOMEN of Science Cheerleader are, in effect, donating their good looks to the advancement of science. In return, they ask only that the world give them the respect that is their due. The U.S. Department of

Commerce Economics and Statistics Administration found that in 2011, the most recent year for which information is available, women held nearly half of all jobs in the U.S. economy but less than a quarter of STEM jobs. Though the report gave many reasons for the disparity, key among them were lack of role models and stereotypes.

In November 2014, British physicist Matt Taylor, project manager for Rosetta, the European Space Agency’s mission to land a spacecraft on a comet, delivered a news update about the mission on live television while wearing a bowling shirt emblazoned with images of scantily clad, voluptuous women with guns. Within hours, Twitter had erupted with comments from irate female scientists concerned

about the impression the shirt would have on women’s desire to enter STEM fields. It even had its own hashtag: #shirtstorm.

Examples of authority figures explicitly endorsing this kind of sexism in science are far too common. In 2015, Nobel laureate Tim Hunt espoused his views on women in science, or “trouble with girls,” at a lunch for women scientists in Seoul: “Three things happen when [women] are in the lab,” he said. “You fall in love with them, they fall in love with you, and when you criticize them they cry.”

Whether they mean to or not, people who look at a young, pretty girl and assume she’s dim contribute to her underachievement in science and math classes—a psychological effect called stereotype threat. Girls who worry they’re at risk of confirming a negative stereotype tend to underachieve in exactly those situations where they’re expected to fail.

“There were times I couldn’t reveal—and I didn’t—to my lab that I was involved in cheer because people would look at me differently, take me less seriously,” Hodges says. “A woman who graduated with an honors degree in neuroscience from Vanderbilt shouldn’t be embarrassed for people to

find out she’s a cheerleader.”

Seated at a table in the museum’s exhibit on the “original supercomputer—the human brain,” Hodges is signing trading cards for visitors, many of them children. Hodges is careful to interrupt our conversation in order to ask the kids who approach her what they’re studying in math or in science.

Later, Hodges asks a group of fourth-grade girls and boys who they imagine when they think of a scientist. They pause, considering the question. Finally, slowly, one child says, “Albert Einstein.”

“Don’t you usually think of a man?” Hodges says. It dawns on the children that yes, they do. How effective are the Science Cheerleaders? That’s a hard thing to measure, until the next generation grows up, chooses careers, and continues marching toward progress. But glimmers of hope flash through the pep rally like light off poms. Toward the end, after all of the youth squads have had their moment in the spotlight, one girl is still cheering above the others. The crowd turns toward the lone voice, and there she is, a tiny blond cheerleader—almost a miniature version of Melissa Hodges. Eyes aglow and poms fluttering, she keeps cheering, alone and unintimidated, while the crowd watches. “What do we love?” she shouts. “*Science!*”

PM

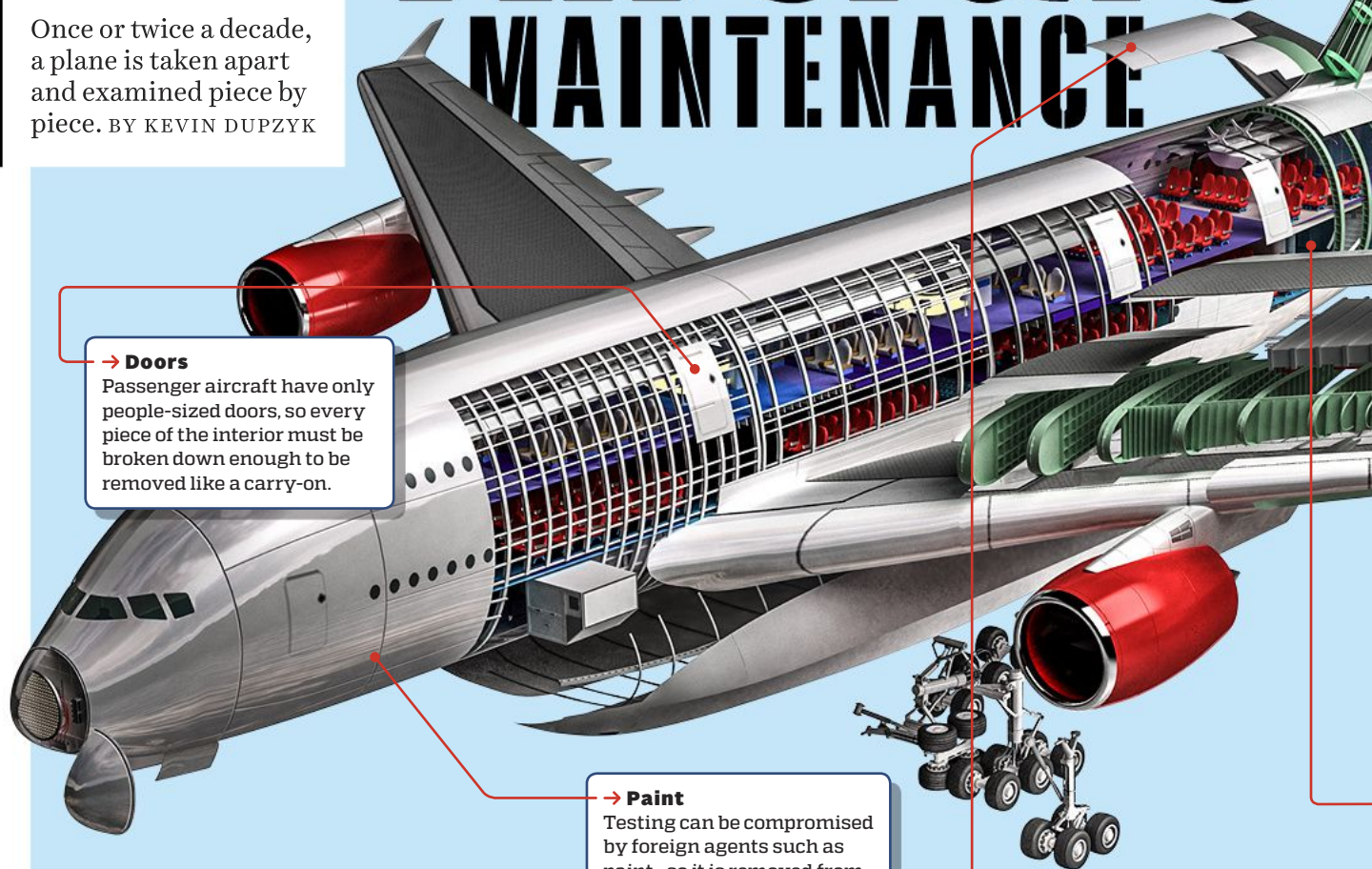
HOW

IT

WORKS

Once or twice a decade, a plane is taken apart and examined piece by piece. BY KEVIN DUPZYK

EXTREME Aircraft MAINTENANCE



→ Doors

Passenger aircraft have only people-sized doors, so every piece of the interior must be broken down enough to be removed like a carry-on.

→ Paint

Testing can be compromised by foreign agents such as paint—so it is removed from various parts.

→ Fuselage Skin

When a technician finds damage, such as molten metal from a lightning strike, the piece is cut out, the space filled, and a new piece of sheet metal called a repair doubler is riveted into place.

After a post-9/11 hangover of merging airlines, tightening security, and shrinking legroom, we're finally back at a point where the most notable thing about air travel is the flying machines. Planes are experiencing the same kind of technological shift as cars, but 35,000 feet up. Airbus is rolling out its A350 family of airliners, built of mostly composite materials, whose wings constantly change shape during flight to maximize efficiency. Boeing has invented a new metal that is lighter than air and should be in planes in ten years.

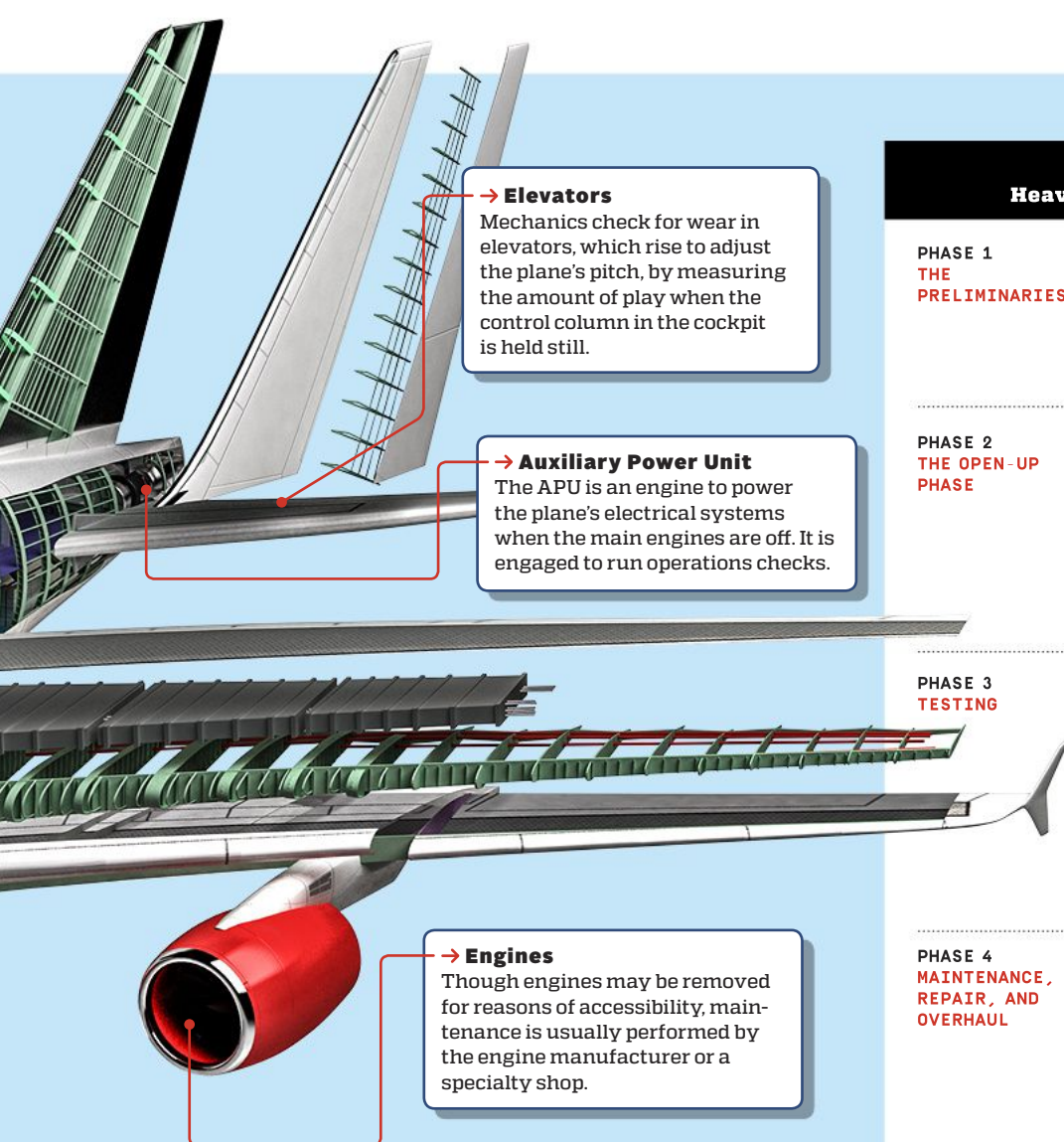
Then there are drones, which just can't stay away from airplanes. An October analysis of 891 drone sightings reported to the Federal Aviation Administration found that 248 had come within 500 feet of a passenger plane. Suppose a drone

hits a brand-new Airbus: Would we know what kind of damage had been done?

We would, because airplane maintenance programs are utterly relentless. Just as cars get minor checkups every 3,000 miles and major service every 60,000, planes follow a rigorous schedule of examinations. The equivalent of the 60,000-mile service is the heavy maintenance visit (HNV). A plane deadheads to a maintenance, repair, and overhaul facility to be completely disassembled so every part can be examined, fixed, or replaced. It's out of commission for a month or more while tens of thousands of man-hours of work are performed. HNVs typically occur every six to eight years and are so expensive that by the time a plane is due for its third, it's usually sold for parts instead.



With thanks to Rayner Hutchinson and Barry Andersch of AAR Corporation, Leonard Kazmerski of HAECO Americas, and Chris Johnson-Pasqua of Boeing.



→ Elevators

Mechanics check for wear in elevators, which rise to adjust the plane's pitch, by measuring the amount of play when the control column in the cockpit is held still.

→ Auxiliary Power Unit

The APU is an engine to power the plane's electrical systems when the main engines are off. It is engaged to run operations checks.

→ Engines

Though engines may be removed for reasons of accessibility, maintenance is usually performed by the engine manufacturer or a specialty shop.

→ Lavatories

Like every other piece, bathroom parts are given unique identifiers and put on special racks so they don't get lost or damaged during the inspection.

Timeline of a Heavy Maintenance Visit

PHASE 1 THE PRELIMINARIES

ARRIVAL

OPERATIONS CHECKS: Pre-dismantlement checks verify the proper functioning of whole-plane systems like hydraulics, pneumatics, electronics, navigation, and pressurization.

PHASE 2 THE OPEN-UP PHASE

INTERIOR DISASSEMBLED: To expose the frame of the aircraft, the cabin lining, ceiling, floorboards, insulation, seats, overhead bins, lavatories, and galley all come out.

EXTERIOR DISASSEMBLED: Body panels and fairings are removed to allow access to the airframe.

PHASE 3 TESTING

GENERAL VISUAL INSPECTIONS: Technicians use flashlights and mirrors to examine external surfaces like the fuselage skin, wings, doors, and landing gear.

DETAILED VISUAL INSPECTIONS: More detailed checking for finer cracks, corrosion, and signs of lightning strikes.

NONDESTRUCTIVE TESTING

PHASE 4 MAINTENANCE, REPAIR, AND OVERHAUL

ROUTINE ITEMS: Replacing parts such as filters or cables at the end of their life cycle and regular upkeep of parts like flaps and ailerons.

NONROUTINE ITEMS: Issues found during testing are reviewed with the airline, which decides what to fix.

UPGRADES: With the plane grounded and accessible, complicated cabin upgrades like new seating can be installed.

PHASE 5 WRAP-UP

TEST FLIGHT AND DEPARTURE: A test flight with an airline representative ensures the plane is ready for passengers.

A Few Ways to Inspect Parts Without Breaking Them

Some inspection techniques—like yanking on a shelf to see if it'll hold—can damage the part being tested. Airplane mechanics use nondestructive inspection techniques to find defects without introducing any new ones.

LIQUID PENETRANT

A liquid dye is applied. After the excess is removed, only dye that seeped into defects remains. A chemical developer makes the dye visible.

EDDY CURRENT

A part is passed through the electromagnetic field of an induction coil. Imperfections in the part cause noticeable changes in the field.

ULTRASOUND

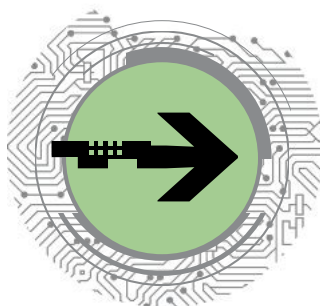
High-frequency sound waves shoot through a part. Imperfections bounce the waves back at irregular intervals.

MAGNETIC PARTICLE

A part is magnetized and coated with a layer of magnetic particles. Defects change the part's magnetic field, visibly disrupting the coating.

X-RAY

A part is exposed to X-rays to create a latent image on film.



POPULAR MECHANICS

G O E S T O T H E

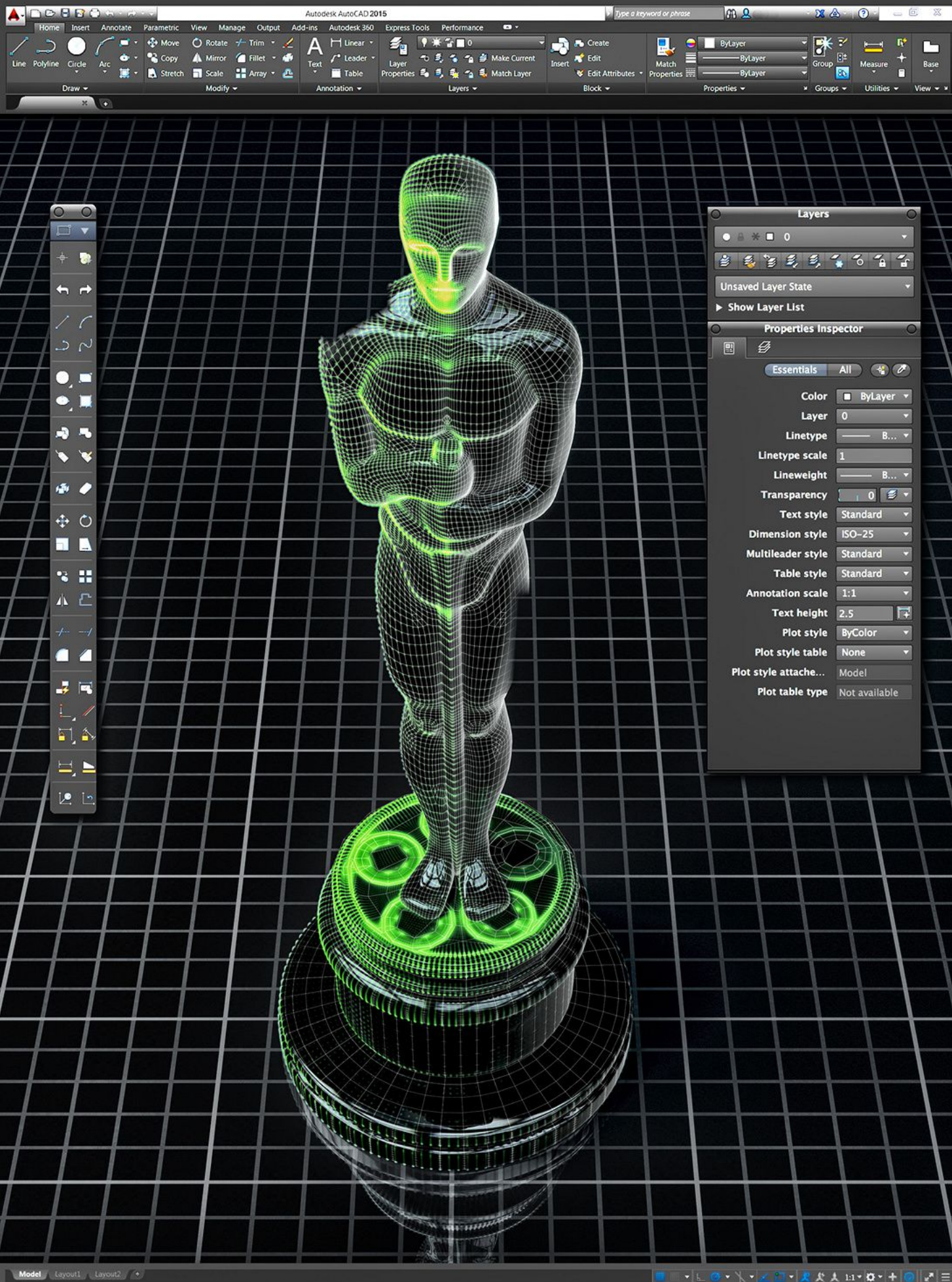
OSCARS

F E A T U R I N G

THE INCREDIBLY SPECIAL EFFECTS AWARDS!



EVERY YEAR, THE MEN AND WOMEN who make movies possible are only briefly recognized, relegated to a two-minute capsule presentation during the Oscars telecast. You know the part of the show: The host mentions the Scientific and Technical Awards ceremony that was held two weeks before, then the broadcast cuts to a young actress shaking hands with older men who look like they'd enjoy doing your taxes. These older men (and a few women!) are geniuses, and they deserve more. This year, in honor of the technology, equipment, lens creators, and software developers behind the people who are behind the people who make our favorite movies, we decided to focus on them. On their achievements. We're also cohosting a cocktail party for them with the Academy this year. We think it'll be fun. We know it's deserved.



A SELECTIVE HISTORY OF THE SCI-TECH AWARDS

1931

The Academy establishes the Scientific or Technical Achievement category at the fourth annual Academy Awards and recognizes the winners at the official ceremony. The first sci-tech Oscars honor noise-reduction recording equipment and highly sensitive black-and-white film.

1952



Thirteen years after *Gone With the Wind* became the first all-color Best Picture, the Academy honors color cinematography. The Eastman Kodak Company and the Ansco Film Division of General Aniline and Film Corp. receive statuettes, and the Technicolor Motion Picture Corp. wins a certificate.

1974

The Scientific and Technical Awards are moved to a separate ceremony. The first year is cohosted by Gregory Peck (left).



1977



The Steadicam, a stabilizer that helps cameramen capture handheld shots without shaking, receives an award. This technology kept scenes like Rocky jogging through Philadelphia and the speeder bike chase in *Return of the Jedi* from looking like *The Blair Witch Project*.



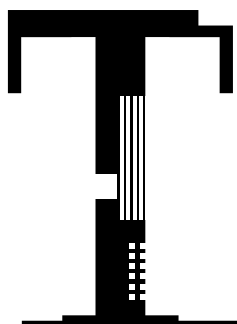
1966

Petro and Paul Vlahos, a father and son, win statuettes for inventing blue screening. The technique permitted Mary Poppins to jump into a painting and Neo to do everything he did in *The Matrix*.



A NIGHT AT THE (OTHER) OSCARS

Last year, Popular Mechanics gained exclusive access to the Sci-Tech Awards.



The ballroom is filled with engineers and Ph.D.'s. Acceptance speeches give shout-outs to Hewlett-Packard, not agents. (These people don't have agents.) Last year's event was hosted by actors Miles Teller and Margot Robbie. They dutifully introduced each award and detailed its recipient's significance—with lighthearted, smart-ass irreverence. While discussing

"voxels," the elements that make up a virtual 3D space, Teller used the word so many times in his presentation that he proposed that the audience take a drink every time someone said it. The crowd loved it. And why not? Unlike the Oscars, the Sci-Tech Awards involve no competition.

Throughout the event there remained a playful tension between old-school Hollywood glamour and the cutting edge of filmic technology. Recipients teased their hosts as much as they were teased themselves. At most Hollywood events, Teller and Robbie would have been the main attraction, but at the Sci-Tech Awards they were struggling to tread water in a sea of brainiacs.

One of the evening's two

Oscar statuettes went to Larry Hornbeck, who in 1987 invented the digital micromirror that's used in Texas Instruments' DLP projectors, which helped end the era of film projectors in theaters. Receiving a standing ovation, Hornbeck, in his early seventies and looking grandfatherly with his glasses and receding hairline, took to the podium and held aloft a DLP chip. "Who would have ever believed . . . that this would change the way that the world sees new cinema?" That prompted some random ecstatic whoops—a reminder that in the land of the Sci-Tech Awards, it's not performances that elicit the greatest audience response. Sometimes, it's a microchip.

—Tim Grierson



Hosts Margot Robbie and Miles Teller with last year's Sci-Tech Awards attendees.

THE AWARDS

Technical Achievement Award

Given for clever technological innovations that have had an impact and contributed to the progress of the film industry. Winner receives a framed certificate.

PREVIOUS WINNER: Peter Braun, MAT-Towercam Twin Peek



Scientific and Engineering Award

Reserved for pieces of technology that have permeated the industry, have possibly spawned imitators, and were very difficult to create. Winner receives a 24-karat gold-plated plaque.

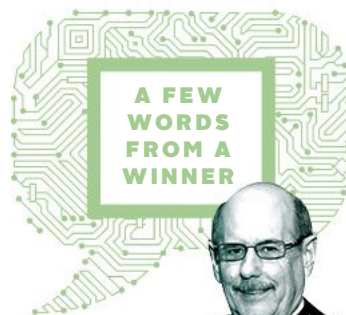
PREVIOUS WINNERS: John Frederick, Bob Myers, Karl Rasche, and Tom Lianza, HP LP2480ZX Professional Display



Academy Award of Merit

Reserved for only the most groundbreaking, important, and widely adopted technological innovations, this award is so difficult to receive it goes years without being given. Winner receives an Oscar. A real one.

PREVIOUS WINNER: Dr. Larry Hornbeck, digital micromirror technology



Dolby Laboratories' David W. Gray created stereo-optical soundtracks and added digital sound to film. He won the Gordon E. Sawyer Award in 2015.

POPULAR MECHANICS: This was a big deal.

DAVID W. GRAY: Absolutely huge. It's not given very often. I believe I was the twenty-fifth recipient. It's the only way for an engineer like me to possibly get an Oscar.

PM: Did you show up in the Sci-Tech clip on the Academy Awards?

DWG: I did. My twelve-minute speech got boiled down to a shot of me being handed the Oscar and saying, "Wow!" I got my one word on national television. It was great.

PM: Twelve minutes is pretty long for an Oscar speech.

DWG: There has never been a time constraint on the Gordon Sawyer or the Bonner awards.

That's one of the benefits of Sci-Tech. You don't get played off.

PM: What do you think we should be paying more attention to in movies?

DWG: I don't think the general public really understands the breadth of what goes into making a motion picture and how technical that process really is. People see visual effects, but I don't know that anybody thinks about the fact that some guy wrote an algorithm that can do that.

PM: Now that you have an Oscar, do you make people refer to you as "Academy Award winner David Gray"?

DWG: No, but my friends tease the shit out of me. They call me "Mr. I Have an Oscar and You Don't."

HOW IT WORKS: THE SCI-TECH AWARDS SELECTION PROCESS

1 THE SUBMISSIONS

After a call is put out each spring, inventors, technicians, scientists, companies, and anyone else who feels they're deserving have until July to file an application.

2 THE FIRST CUT

An executive committee goes through the submissions, looking for innovations that have changed filmmaking. The finalists are then assigned to surrogate committees for investigation.

3 THE INVESTIGATION

The Academy issues a press release announcing the finalists and inviting others to submit similar technologies. Over three months, the committee investigates every aspect of the nominated technology.

4 THE REPORT

The surrogate committee passes reports on worthy nominees to the executive committee. The executive committee makes another cut and passes the submissions on to the Board of Governors.

5 THE BOARD OF GOVERNORS

The Board of Governors is made up of fifty-one Academy members, including actors, writers, producers, and costume designers. Those members vote on who should actually receive awards.

6 THE WINNERS

All applicants, whether they won or not, are told via letter if they were selected and why or why not. The Academy issues a press release in early January announcing the winners.



1996



IMAX Corp. receives an award for its signature wide-angle films and theaters.

2008

Ed Catmull, the president of Walt Disney and Pixar and one of the developers of the RenderMan animation software first used in *Toy Story*, is honored with the Gordon E. Sawyer Award, basically the Sci-Tech version of the lifetime achievement award.



A FEW OF THIS YEAR'S NOMINEES

A brief look at some of the more notable (and easier to understand) achievements under consideration for this year's awards.



↑ AIRCOVER INFLATABLE'S INFLATABLE AIRWALL

Before the Airwall, large special-effects screens were laboriously constructed of lumber and metal, then torn down and thrown away after filming. The Airwall avoids that waste of time, materials, and effort. The reusable inflatable screens can be attached to shipping containers in different combinations to create nearly any size and shape. **RECENT CREDITS:** *Godzilla*, *Avengers: Age of Ultron*



Zoe Saldana using FACETS technology for *Avatar*.

↑ WETA DIGITAL'S FACETS DIRECTABLE FACIAL MOTION CAPTURE

FACETS technology turns actors' faces into computer-generated creatures in real time. The system uses a headset that looks like a pop star's wireless microphone to place a camera directly in front of actors' faces, allowing a computer to capture their expressions close up and translate them into a CGI face. Old technology required facial and body acting to be done separately. The technology also lets actors see their movements transformed into rough estimations of their characters in real time, helping them to adjust to best fit the animation. **RECENT CREDITS:** *Avatar*, *The Hobbit*



↑ WETA DIGITAL'S ODIN LARGE-SCALE, MASSIVELY PARALLEL, DISTRIBUTED, MULTI-PHYSICS SIMULATION SYSTEMS

Odin makes all the special effects you never notice: background waterfalls, burning cities, rooms full of gold coins. The computer platform networks multiple machines to create massive effects, allowing small details to be simulated in a matter of hours rather than days. **RECENT CREDITS:** *Prometheus*, *Godzilla*



↑ CLAIRMONT CAMERA SQUISHY LENS AND IMAGE SHAKER

Often used in dream sequences, Squishy (pictured) is a soft optical element that creates an image that's clear in the center and foggy on the periphery. The Image Shaker is two pieces of glass with liquid in between that pan and tilt on separate axes using two separate motors. This makes you think there's an earthquake when nothing in the scene is actually moving. **CREDITS:** *X-Men*, *Saving Private Ryan*

AN APPRECIATION

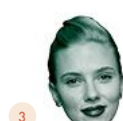
A note of thanks, assembled from the words of notable Sci-Tech Awards hosts.



1 Miles Teller, 2015



2 Maureen Stapleton, 1979



3 Scarlett Johansson, 2005



4 Jamie Lee Curtis, 1995



5 Arnold Schwarzenegger, 1984

"Many moviegoers would attribute the director as the storyteller of a film. And while it is true that the vision of a movie is shaped by a director, that vision could only come together through the talents of the hundreds of people with whom the director collaborates." [1] "Anyone who ever sees a movie, let alone works in one, owes an enormous debt to the technicians and inventors who are constantly striving to improve the medium." [2] "The minds behind the machinery." [3] "While we may not understand precisely what [they] accomplished, you and I, the moviegoing public, are all the beneficiaries of their vision and dedication." [4] "All of us who appreciate progress in the art of motion pictures appreciate the contributions of those scientists and technicians." [5]

POPULAR MECHANICS PRESENTS

THE INCREDIBLY SPECIAL EFFECTS AWARDS

Our second annual look at the year's most stunning technological moments in film, including a high-wire act, a movie shot entirely on an iPhone, and Tom Cruise holding his breath. **BY TIM GRIERSON**

Tom Hardy, largely unaided by CGI, in *Mad Max: Fury Road*.



BEST PRACTICAL EFFECTS

MAD MAX: FURY ROAD

THOUGH SOME SKIES were altered and stunt performers' cables were erased in postproduction, *Mad Max: Fury Road* emphasized practical effects. More than 150 vehicles were built for the shoot—and then destroyed. By the end of the film, “we probably had only ten left,” stunt coordinator Guy Norris says. On the heaviest stunt days, Norris would incorporate 150 stunt actors. His goal was controlled chaos. “I designed the action so that it was like being in warfare,” he says. “When you’re

on the top of the tanker, even though the camera might be to the left-hand side seeing something happen, an entire battle is going on over to the right-hand side. We would develop sequences so that you could actually shoot it in one line.” All of that sophisticated stuntwork required some unsophisticated preparation: toy cars. “We’d start out in the dirt with all of the drivers with a model car, and we would plan the whole run. It was like rehearsing a football play.” Only with a few more explosions.

BEST STUNT

MISSION: IMPOSSIBLE—ROGUE NATION

Tom Cruise may have hung off the side of an airplane for *Mission: Impossible—Rogue Nation*, but stunt coordinator Wade Eastwood doesn’t consider it the film’s biggest challenge. “The underwater scene was the hardest to shoot, to prep for, to do, and to watch,” he says. In the continuous six-minute take, Cruise (as secret agent Ethan Hunt) holds his breath while submerged in an underground tank searching for a crucial computer chip. Eastwood describes how he and Cruise pulled it off.

THE BREATH

“We started training early with Tom. We hired a world champion at holding his breath. When you feel you need air, it’s about training your mind not to want to take that gasp. It’s all mental.”

THE WIRE

To simulate the effect of an underwater turbine pushing Hunt backward, Eastwood attached wires to Cruise. “Every time we pull him with the wires, we’re squeezing

the harness against his diaphragm so that he wants to expel the air. And there are buoyancy issues: When you pull someone, their body might go up or down through the water. We had to play with pulling from one of two different places. If he started going up, we would put more pressure on our down-line pull so we could keep him on a level plane.”

THE COUNTDOWN

The CG work focused on enhancements to the set, but the central stunt—Cruise holding his breath—is real. Which made it scary. “As soon as you go underwater, you’re on a countdown. You can plan it all day, but once you take that breath and go underwater, the clock starts ticking. And so everything is a challenge.” Cruise had a signal for when he needed to break for air. But Eastwood couldn’t always wait for that. “There was only one rule I had: If there was any doubt whatsoever, we go in—even if we were in the shot, even if we had to do it again.” ▶



Director Sean Baker shoots a scene in *Tangerine*.

BEST USE OF AN IPHONE

TANGERINE

FILMMAKER SEAN Baker's *Tangerine* is a funny, touching look into the lives of two transgender Los Angeles prostitutes. Just as

memorable as the script, however, is the film's innovative handheld camerawork, which captures the intimacy of the characters' lives as well as the sun-splashed streets of Hollywood. Baker shot it all on an iPhone 5s.

"There's a very specific light to L.A.," Baker says. "It's caused by pollution. The particles, during sunset, light up and become this beautiful orange hue." Baker used an anamorphic adapter lens from Moondog Labs, allowing him to "spread the light horizontally across the frame." Using FiLMiC Pro (a focus and exposure app) and Smoothee (a device to keep shots steady), Baker and cinematographer Radium Cheung tested for a month before filming.

Baker valued the iPhone's size as much as he did the price. "If you're trying to combine narrative and documentary, and to capture real street life—then you are one step away from having a hidden camera," he explains. The type of camera he uses next depends on the project. But if he uses an iPhone, he'll be sure to get the newest model. "We shot *Tangerine* a year and a half ago. You don't even need Smoothee anymore, because the stabilizer within the new iPhone 6 is so wonderful."

BEST STOP-MOTION FILM

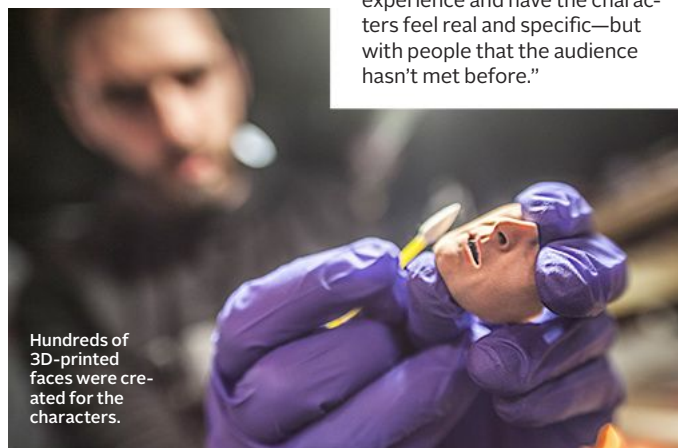
ANOMALISA

When Oscar-winning screenwriter Charlie Kaufman staged a play called *Anomalisa* back in 2005 in Los Angeles, he never intended to make it a film. But when he was approached to adapt it for animation, stop-motion seemed the perfect vehicle to tell this funny, poignant story about a lonely motivational speaker who falls in love with an Akron office worker.

"There's a certain fragility in this form of animation—you can see the animation being done," says Kaufman, who codirected with Duke Johnson. "We chose to leave the seams on the characters' faces because we wanted to have that presence of the unseen animator in their lives."

Anomalisa took three years

to create. It started with recording the actors' dialogue and then constructing the puppets and sets. The characters' bodies were made of silicone, while the heads were 3D-printed and adorned with yak hair. As time-consuming as it is, this particular brand of animation afforded them massive creative freedom. "We wanted these characters to feel real, and we ultimately settled on modeling them after real people," Johnson says. "We photographed real people and we brought in a sculptor to translate them. We chose a hairstyle, we chose a body type. Normally for live action, you have to use stars that, when people see them, they immediately identify with them in some way. We wanted to take advantage of that experience and have the characters feel real and specific—but with people that the audience hasn't met before."



Hundreds of 3D-printed faces were created for the characters.

BEST FIGHT SCENE

KINGSMAN: THE SECRET SERVICE

COLIN FIRTH WON an Oscar in 2011 for playing a stuttering monarch in *The King's Speech*. Not the toughest character. But in *Kingsman: The Secret Service*, Firth proved to be

one of 2015's most surprising badasses—especially during a nearly three-minute action sequence in which the killer spy takes on an entire church of hateful conservatives. Firth drives knives through skulls, burns off faces with a high-powered lighter, throws a man through a beautiful stained-glass window, and puts an axe in at least one neck.

Those three minutes, which took nine days to film, are

meant to look like one continuous shot, but cinematographer George Richmond says that it actually involved painstakingly stitching together several mini moments. Which meant making the poor stuntmen, led by stunt coordinator and second unit director Brad Allan, do more than a few reshoots. "To make the shots seem seamless," Richmond says, "sometimes you're doing twenty or twenty-five takes just to get the beginning

and the end right." They also used invisible wirework and digitally replaced faces.

The result is a fever dream of stunts and visual effects, but the hardest part was coordinating the lighting. "When the camera is moving around in 360 degrees, it's never good for the light," he says. Richmond positioned the lights outside the windows and on the ceiling, and erased the overheads during postproduction.



MOST SPECIFIC SAND

THE MARTIAN

THOUGH PLENTY OF effects shots went into director Ridley Scott's *The Martian*, there was one set piece that couldn't be rendered on a computer: the

sand. Production designer Arthur Max knew that the dunes in Jordan could be used to replicate other planets, but to nail Mars' exact look, he and

Joseph Gordon-Levitt as Philippe Petit in *The Walk*.

MOST VERTIGINOUS MOMENT

THE WALK

The centerpiece of director Robert Zemeckis's *The Walk* is its re-creation of Philippe Petit's 1974 tightrope walk between the World Trade Center towers. Visual-effects supervisor Kevin Baillie explains how the sequence took shape.

1. CREATING THE BACKGROUND

The Twin Towers scenes were shot on a green screen, which required Baillie's team to construct New York from scratch. "New York today looks vastly different from what it did back in 1974," he says. "We couldn't go there and take a bunch of photos and call it a day. We ended up pulling thousands of reference photos from thousands of sources. We built every building, every window, every hot-dog stand in the street."

2. MAKING IT REAL FOR THE CAST

The set was forty by

sixty feet, with the actors, including star Joseph Gordon-Levitt, standing twelve feet off the ground. "If you fell off from that height, you could hurt yourself, so there is a little bit of inherent fear built in there," Baillie says. To increase the anxiety for the actors, Baillie's team put together reference photos to give the performers an idea of what the ground would have looked like from the top of the towers. A Simul-Cam system "showed a real-time composite of video-game quality. You could see through the lens of the camera where the horizon was, how far down things were, vanishing points, so the actors knew that was what the camera was seeing, even though they just saw a sea of green."

3. BUILDING FEAR

To provoke vertigo in the audience, Baillie, Zemeckis, and cinematographer Dariusz Wolski used two tricks.

"If you start looking toward a horizon and you raise the camera above Philippe and show this giant depth below, that's one thing that definitely creates vertigo," Baillie explains. "And if you start a shot with the edge of the building in the frame and you move over it as if you're leaning over the edge to see down, it gives that feeling that the world is dropping beneath you."

4. PERFORMING THE WALK

Gordon-Levitt trained with Petit to learn wire walking, but Baillie also used a little digital trickery to assist his star. "He had a cable, a safety harness connected to his back," Baillie reveals. "But it wasn't there to support at all because if they put any tension on that, it throws you off balance when you're walking. It is only there to protect you if you fall. Luckily, he never did." That harness could be digitally erased, as

could a bar they built for Gordon-Levitt—"a twenty-foot-long steel plank that was painted green, and we would raise it up below the wire. It was still twelve feet off the ground, but it had a slot going down the middle so that Joe's foot could still wrap around the wire. If he started to lose his balance, there was a plank there for him to rest his foot and regain his balance. Of course, digitally, we would erase all that, and it would look like just the wire was there."

To mimic Petit's most difficult moves on the wire—the few moves that Gordon-Levitt couldn't handle—Zemeckis recruited a former Cirque du Soleil performer, Jade Kindar-Martin. From there, Baillie would place Gordon-Levitt's face on top of Kindar-Martin's, invisibly marrying the actor's performance to the wire walker's. "There are about forty shots in the movie where it was a completely digital version of Joe's face," Baillie says.

ANDROID OF THE YEAR

Alicia Vikander, *Ex Machina*

RUNNER-UP
BB-8, *Star Wars: The Force Awakens*



TOUGHEST CAMERA



CANON EOS 5D MARK II

In *Meru*, codirector Jimmy Chin and two fellow mountaineers filmed their attempt to ascend Meru Peak in the Himalayas. Chin's Mark II repeatedly filled with mist—the result of condensation created by warm bodies stuffed into a portaledge at minus 20 degrees. Chin's solution: his camp stove. Holding the lens over the flame, he repeatedly burned out the moisture without melting anything important.

his team needed to do a little mixing. They referred to images sent back from the Mars rover Curiosity and consulted with NASA's Jet Propulsion

Laboratory and the Johnson Space Center. And then they experimented. "We took some samples back from Jordan, parts of stone and parts of

sand, and we matched them by getting a variety of soils and gravels from Hungary," Max says. "It's a lot like mixing paint. We made a very large batch—

about 2,500 cubic tons." Mixing ended up being the easy part. Of the eleven-week preproduction, four were spent getting the sand loaded onto the set. **PM**

Choose Life Grow Young with HGH

From the landmark book *Grow Young with HGH* comes the most powerful, over-the-counter health supplement in the history of man. Human growth hormone was first discovered in 1920 and has long been thought by the medical community to be necessary only to stimulate the body to full adult size and therefore unnecessary past the age of 20. Recent studies, however, have overturned this notion completely, discovering instead that the natural decline of Human Growth Hormone (HGH), from ages 21 to 61 (the average age at which there is only a trace left in the body) and is the main reason why the the body ages and fails to regenerate itself to its 25 year-old biological age.

Like a picked flower cut from the source, we gradually wilt physically and mentally and become vulnerable to a host of degenerative diseases, that we simply weren't susceptible to in our early adult years.

Modern medical science now regards aging as a disease that is treatable and preventable and that "aging", the disease, is actually a compilation of various diseases and pathologies, from everything, like a rise in blood glucose and pressure to diabetes, skin wrinkling and so on. All of these aging symptoms can be stopped and rolled back by maintaining Growth Hormone levels in

the blood at the same levels HGH existed in the blood when we were 25 years old.

There is a receptor site in almost every cell in the human body for HGH, so its regenerative and healing effects are very comprehensive.

Growth Hormone first synthesized in 1985 under the Reagan Orphan drug act, to treat dwarfism, was quickly recognized to stop aging in its tracks and reverse it to a remarkable degree. Since then, only the lucky and the rich have had access to it at the cost of \$10,000 US per year.

The next big breakthrough was to come in 1997 when a group of doctors and scientists, developed an all-natural source product which would cause your own natural HGH to be released again and do all the remarkable things it did for you in your 20's. Now available to every adult for about the price of a coffee and donut a day.



GHR now available in America, just in time for the aging Baby Boomers and everyone else from age 30 to 90 who doesn't want to age rapidly but would rather stay young, beautiful and healthy all of the time.

The new HGH releasers are winning converts from the synthetic HGH users as well, since GHR is just as effective, is oral instead of self-injectable and is very affordable.

GHR is a natural releaser, has no known side effects, unlike the synthetic version and has no known drug interactions. Progressive doctors admit that this is the direction medicine is seeking to go, to get the body to heal itself instead of employing drugs. GHR is truly a revolutionary paradigm shift in medicine and, like any modern leap frog advance, many others will be left in the dust holding their limited, or useless drugs and remedies.

It is now thought that HGH is so comprehensive in its healing and regenerative powers that it is today, where the computer industry was twenty years ago, that it will displace so many prescription and non-prescription drugs and health remedies that it is staggering to think of.

The president of BIE Health Products stated in a recent interview, I've been waiting for these products since the 70's. We knew they would come, if only we could stay healthy and live long enough to see them! If you want to stay on top of your game, physically and mentally as you age, this product is a boon, especially for the highly skilled professionals who have made large investments in their education, and experience. Also with the failure of Congress to honor our seniors with pharmaceutical coverage policy, it's more important than ever to take pro-active steps to safeguard your health. Continued use of GHR will make a radical difference in your health, HGH is particularly helpful to the elderly who, given a choice, would rather stay independent in their own home, strong, healthy and alert enough to manage their own affairs, exercise and stay involved in their communities. Frank, age 85, walks two miles a day, plays golf, belongs to a dance club for seniors, had a girl friend again and doesn't need Viagra, passed his drivers test and is hardly ever home when we call - GHR delivers.

HGH is known to relieve symptoms of Asthma, Angina, Chronic Fatigue, Constipation, Lower back pain and Sciatica, Cataracts and Macular Degeneration, Menopause, Fibromyalgia, Regular and Diabetic Neuropathy, Hepatitis, helps Kidney Dialysis and Heart and Stroke recovery.

For more information or to order call 877-849-4777

www.biehealth.us

©copyright 2000

New! Doctor
Recommended

The Reverse Aging Miracle

RELEASE YOUR OWN GROWTH HORMONE AND ENJOY:

- Improved sleep & emotional stability
- Increased energy & exercise endurance
- Loss of body fat
- Increased bone density
- Improved memory & mental alertness
- Increased muscle strength & size
- Reverse baldness & color restored
- **Regenerates Immune System**
- Strengthened heart muscle
- Controlled cholesterol
- **Normalizes blood pressure**
- Controlled mood swings
- Wrinkle disappearance
- Reverse many degenerative disease symptoms
- Heightened five senses awareness
- Increased skin thickness & texture

All Natural
Formula

This program will make a radical difference in your health, appearance and outlook. In fact we are so confident of the difference GHR can make in your life we offer a 100% refund on unopened containers.

A Product of
Global Health
Products

1-877-849-4777

www.biehealth.us

BIE Health Products
3840 East Robinson Road
Box 139
Amherst, NY 14228

GHR

DIV 2037839 ON



PROJECT

THE
FIREWOOD
RACK

An elegant, original design makes winter's most functional piece of furniture also its most handsome.

BY RICHARD ROMANSKI

When we set out to design an indoor firewood rack, we wanted it to be sturdy and made from materials you can buy at any home center or lumberyard. So we designed our rack from ordinary 4 x 4 lumber, steel angles, and flat stock. To turn a rough 4 x 4 into flawless 2 x 2 stock is no great mystery, and we show you how. But you do need a table saw and a benchtop thickness planer. If you don't own those machines, you can still build this rack by ordering clear 2 x 2 stock from a lumberyard. This material is

PROJECT

quite attractive and will make the rack look lighter since its actual dimensions are $1\frac{1}{2} \times 1\frac{1}{2}$ inches, whereas our material measures a full 2 inches. Going this route is a good option, and the rack will still be plenty strong. Either way, let's get started.

MAKE THE LEGS

Sight down each piece of 4 x 4, and mark off four rough lengths that are flat and straight with few or no knots. Crosscut these four lengths. On each piece put a reference mark on the end grain to indicate the flattest side. In the diagram ("How to Take a 4 x 4 Down to a 2 x 2," opposite), the reference side is shown with a small triangle.

Begin by running each 4 x 4 length through the benchtop planer with the reference surface facedown. Then take a light pass to surface-plane the opposite face. Repeat this operation on the remaining three pieces. Now flip each piece over end to end, lower your planer's thickness setting, and run each piece through the planer again. Continue this operation and sequence until all four pieces are flat, parallel, and the same dimensional thickness.

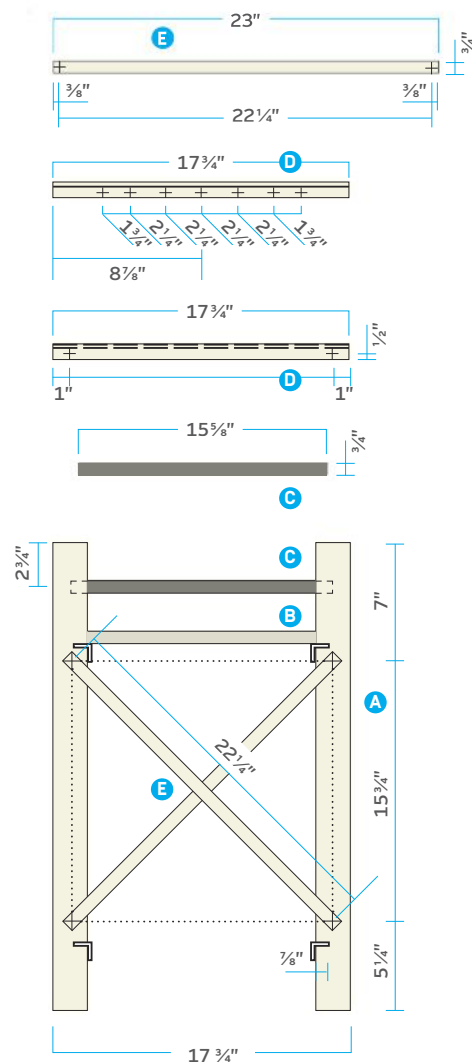
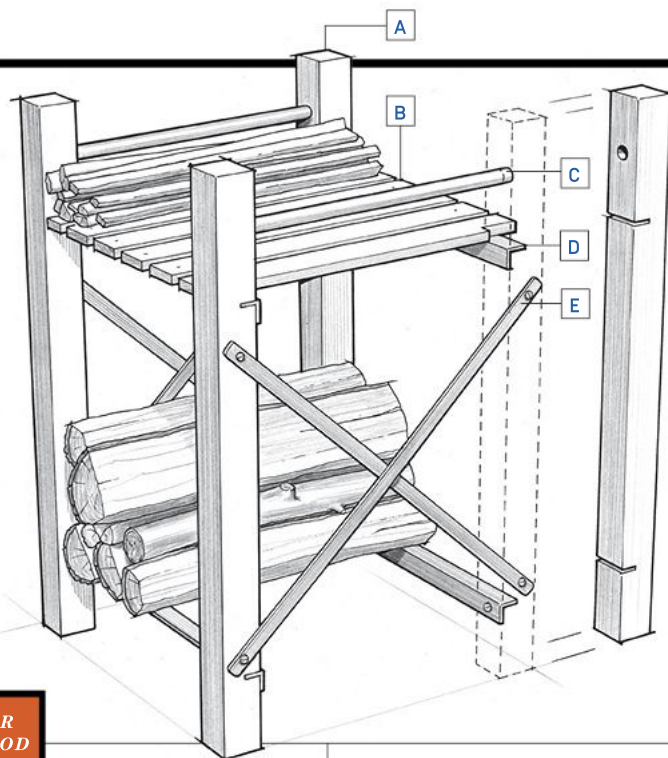
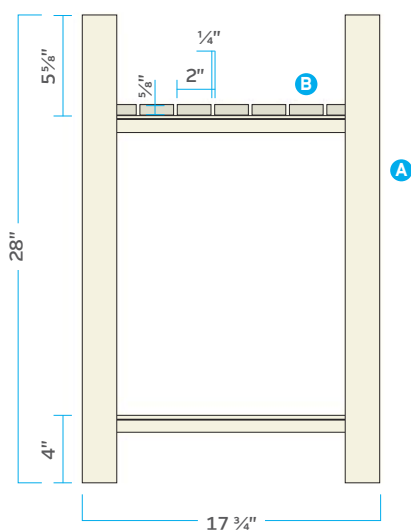
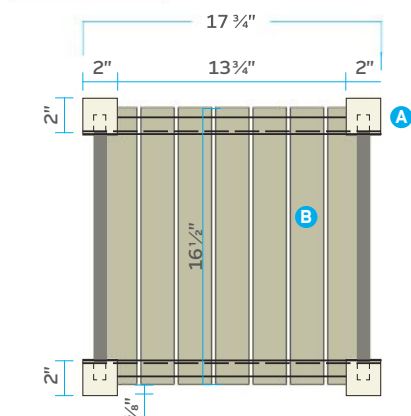
At the table saw set up a standard 50-tooth combination blade and raise it to around 2 inches. Adjust the fence for $2\frac{3}{8}$ -inch-wide rip. Choose the best square edge relative to the freshly planed faces, and run this edge against the fence. Flip the workpieces over with the same edge against the fence, and finish ripping through the thickness of the 4 x 4. The waste piece from this step will become a slat for the top.

Using the sawn surface as the reference facedown against the in-feed table of the planer, make a couple of very light passes. Flip the workpieces over and plane the opposite surface. Make another couple of light passes. The wide faces of the rectangle you've produced should be flat, straight, and parallel to each other.

Return to the table saw. Choose an edge that's square to one of the freshly planed surfaces. Run that edge against the fence. Rip the four legs to $2\frac{3}{16}$ inches wide.

Plane the workpiece to its finished dimensions. First make a very light pass with the freshly sawn surface facedown on the in-feed table. Turn each leg

INDOOR FIREWOOD RACK



THREE CRUCIAL STEPS

One jig for the drill press helps to ensure accurate drilling. Another jig helps to ensure accurate assembly. Both are built with nothing more than pieces of scrap.

FIGURE 1

Use a fence and end stop to accurately position the steel angles on the drill-press table. Measure, and then center-punch the location of each hole.

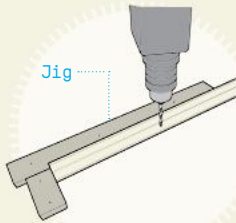


FIGURE 2

Three pieces of scrap nailed to plywood ensure accuracy when attaching the steel angles. Scrap wedged between the legs holds them in place.

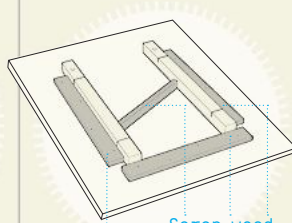
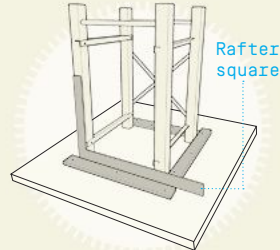


FIGURE 3

Stand the leg assembly in the jig to fasten the crossbraces. Place the blade of a rafter square along the jig and the tongue along the leg.



90 degrees and make another pass through the planer. Reduce the height setting of the thickness planer and repeat this process until all the legs are exactly 2 inches square.

Plane the remaining slat pieces to their finished thickness. Rip the slats to finished width at the table saw. Crosscut the slats and the dowels to finished length.

Now crosscut the legs to finished length. Measure down one face of each leg and lay out a centerline for the dowel hole. On the drill press, drill a 1-inch-deep hole. On the same face of each leg draw a line from each end to locate the groove for the steel angle.

Set the table-saw blade to slightly more

than $\frac{7}{8}$ inch high and, using the miter gauge, cut the groove for the steel angle. Complete each groove by taking a wood file and making a slight chamfer on the bottom edge of the groove.

METALWORK

Crosscut four pieces of steel angle stock to finished length. Use a mill file to square the ends and round off any sharp corners. Lay out, center-punch, and drill the holes in the ends of these pieces, which will allow them to be mounted to the legs.

MATERIALS

Part	Qty	Size and Use
A	4	2" x 2" x 28" leg
B	7	$\frac{5}{8}$ " x 2" x 16 $\frac{1}{2}$ " slat
C	2	$\frac{3}{4}$ " x 15 $\frac{5}{8}$ " dowel
D	4	1" x 1" x 17 $\frac{3}{4}$ " steel angle support
E	4	$\frac{1}{8}$ " x $\frac{3}{4}$ " x 23" steel flat brace

Shopping List

2	4" x 4" x 8' Douglas fir
2	$\frac{1}{8}$ " x 1" x 36" steel angle
2	$\frac{1}{8}$ " x $\frac{3}{4}$ " x 48" steel flat
1	$\frac{3}{4}$ " x 36" hardwood dowel
1	pkg. No. 10 x 1 $\frac{1}{4}$ " pan-head screws
1	pkg. No. 8 x $\frac{5}{8}$ " pan-head screws
1	qt tung-oil finish
1	8 oz oil dark-wood stain
1	pack 150-grit sandpaper

TIP

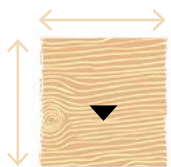
The dimensions and parts shown above are predicated on actual 2 x 2 stock. You will have to adjust these if you choose to use 1 $\frac{1}{2}$ " x 1 $\frac{1}{2}$ " leg stock.

HOW TO TAKE A 4 x 4 DOWN TO A 2 x 2

BEGIN

Crosscut clear stock from an ordinary 4 x 4. Triangle indicates reference surface.

START DIMENSION: 3 $\frac{3}{8}$ " x 3 $\frac{3}{8}$ "



PLANER CUT #1

Put the best face down against the in-feed table, and plane. Then plane the surface parallel to it.

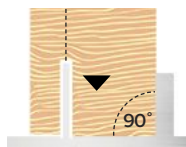
FINISHED DIMENSION: 3 $\frac{3}{8}$ " x 3 $\frac{3}{16}$ "



TABLE-SAW CUT #1

Select a face perpendicular to the one you just planed and put that face against the fence. Rip, flip, and rip again.

FINISHED DIMENSION: 2 $\frac{3}{8}$ " x 3 $\frac{3}{8}$ "



PLANER CUT #2

Put the sawn face against the in-feed table. Plane to 2 $\frac{3}{16}$ inches thick.

FINISHED DIMENSION: 3 $\frac{3}{8}$ " x 2 $\frac{3}{16}$ "



TABLE-SAW CUT #2

Select a planed face that has an edge square to it. Put the squared edge against the fence and rip to 2 $\frac{3}{16}$ inches.

FINISHED DIMENSION: 2 $\frac{3}{16}$ " x 2 $\frac{3}{16}$ "

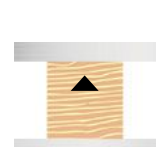


PLANER CUT #3

Put the sawn face on the in-feed table.

Plane, turn 90 degrees, and plane. Repeat until part is 2 inches on each face.

FINISHED DIMENSION: 2" x 2"





I AM NOT A RUG

As few as 3,200 wild tigers remain. Poaching for their skins, bones and other parts is the greatest immediate threat to their survival.

Find out what you can do to stop wildlife crime.



STOP WILDLIFE CRIME
IT'S DEAD SERIOUS

worldwildlife.org/wildlifecrime

PROJECT

INDOOR FIREWOOD RACK

On two of the steel angle pieces measure and mark the row of holes to fasten the slats. Clamp a wood fence ½ inch back from the centerline of your drill-press chuck to position the steel angle (Fig. 1, as shown on page 93). Note: It is important to be accurate in making this row of holes. You need consistency in two dimensions—hole to hole along the length and centered across the width of the steel angle. If you don't drill this row of holes precisely, you'll have a difficult time fastening the slats.

Next crosscut the steel flat stock, round off any sharp corners with a mill file, center-punch, and drill a hole near the end to mount the flat to the legs.



To make the steel angle fit properly, file a bevel on the corner of the groove in the wood.

PREFINISH AND ASSEMBLY

Sand all the wood pieces with 150-grit sandpaper and ease all sharp corners on the legs and slats. Finish with a wipe-on coat of tung oil to the legs and slats. Stain the dowels dark brown or ebony. Clean the steel pieces with No. 00 steel wool and denatured alcohol, then apply tung oil. Let the oil soak into the wood and steel before wiping off excess.

Make an assembly jig (Fig. 2) consisting of a piece of plywood and three strips of wood to help you assemble the legs and two pieces of steel angle. The jig keeps the legs parallel during assembly, and a piece of scrap wood wedged between the legs forces them against the jig's side pieces.

Place the steel angles into their grooves, drill a ⅝-inch pilot hole into each leg, and drive the pan-head screw to fasten the steel angle to the legs.

Now take these two assemblies (of two legs and two steel angles) and stand them up in the same jig. Clamp a rafter square in position (Fig. 3). Measure 7 inches from the top of each leg, and make a small mark with an awl to locate the position of the screw that fastens the flat steel crossbrace, then drill a ⅝-inch pilot hole in each leg. Fasten the

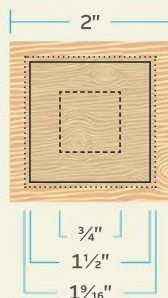
crossbrace to the leg with a No. 10 screw, but don't fully tighten it. Repeat on the opposite piece of flat stock. Now swing the bottom of either piece of flat stock into position. Center it by eye on the lower face of the leg; fasten in place, and tighten the upper screw. Repeat the fastening procedure on the opposite piece of flat stock and on the opposite side of the rack.

COMPLETE THE RACK

Predrill a shallow ⅛-inch pilot hole near the ends of five slats. Locate these by making a center mark in the slat's width and then measuring 1 inch in from the end. Mark the pilot-hole position with an awl.

Fasten the five center slats to the top. Use a jigsaw to cut the notches in the end slats. Next, use the hole in the steel angle as a guide and use an awl to mark the pilot hole. Remove each end slat and predrill the pilot hole, then fasten in place.

Touch up any uneven areas with tung-oil finish. Let the finish dry thoroughly before putting your rack into service. You may notice that the finish gives off a slightly nutty aroma if the rack is placed close to a wood-stove or fireplace. That will fade with time, but it reminds you of your craftsmanship when the rack is new.



THE ELUSIVE 2 X 2 AND THE NEXT BEST THING

A full-dimension 2 x 2 (2 inches wide by 2 high) is not a typical size of lumber. An old-fashioned lumberyard with a millwork shop might be able to make it for you. But most lumberyards and home centers can order you nominal 2 x 2 stock (1½ x 1½ inches), or you can get it from lumber suppliers on the Web. It's also helpful to know what to ask for. Some lumber suppliers will call it 2 x 2; others call it baluster stock. This can be as large as 1⅞ x 1⅞ inches to as small as ¾ x ¾ inch.

HARBOR FREIGHT

QUALITY TOOLS AT RIDICULOUSLY LOW PRICES

**How Does Harbor Freight
Sell GREAT QUALITY Tools
at the LOWEST Prices?**

We have invested millions of dollars in our own state-of-the-art quality test labs and millions more in our factories, so our tools will go toe-to-toe with the top professional brands. And we can sell them for a fraction of the price because we cut out the middle man and pass the savings on to you. It's just that simple! Come visit one of our 600 Stores Nationwide.

20% OFF

ANY SINGLE ITEM

Limit 1 coupon per customer per day. Save 20% on any 1 item purchased. *Cannot be used with other discount, coupon or any of the following items or brands: Inside Track Club membership, extended service plan, gift card, open box item, 3 day parking lot sale item, compressors, floor jacks, saw mills, storage cabinets, chests or carts, trailers, trenchers, welders, Admiral, CoverPro, Daytona, Diablo, Franklin, Hercules, Holt, Jupiter, Predator, Slik-Tek, StormCat, Union, Vanguard, Viking. Not valid on prior purchases. Non-transferable. Original coupon must be presented. Valid through 5/5/16.



FREE

WITH ANY PURCHASE
3-1/2" SUPER BRIGHT
NINE LED ALUMINUM
FLASHLIGHT



LOT 69052 shown
69111/62522/62573

\$4.98
VALUE

LIMIT 1 - Cannot be used with other discount, coupon or prior purchase. Coupon good at our stores, HarborFreight.com or by calling 800-423-2567. Offer good while supplies last. Shipping & Handling charges may apply if not picked up in-store. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one FREE GIFT coupon per customer per day.



US*GENERAL

26", 4 DRAWER TOOL CART
LOT 95659 shown
61634/61952

• 580 lb. Capacity

SAVE \$250

Customer Rating ★★★★★

\$999
~~\$1599~~
comp at \$349.99

68511395

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

18 VOLT CORDLESS 3/8" DRILL/DRIVER WITH KEYLESS CHUCK
drillmaster
LOT 69651
62868/62873
68239 shown

Includes one 18V NiCd battery and charger.

SAVE 65%

Customer Rating ★★★★★

\$1699
comp at \$49.21

68487040

LIMIT 6 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

ADJUSTABLE SHADE AUTO-DARKENING WELDING HELMET
EDUCATIONAL ELECTRIC WELDING
LOT 61611
46092 shown

SAVE 49%

Customer Rating ★★★★★

\$40
~~\$49.99~~
comp at \$79.99

68464681

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

16 OZ. HAMMERS WITH FIBERGLASS HANDLE

PITTSBURGH

CLAW LOT 69006
60715/60714

RIP LOT 47873 shown
69005/61262

Customer Rating ★★★★★

SAVE 83%

\$299
comp at \$17.99

68447234

LIMIT 7 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

CENTRAL PNEUMATIC 3 GALLON, 100 PSI OILLESS PANCAKE AIR COMPRESSOR

SAVE 55%

LOT 60637
61615
95275 shown

\$399
comp at \$89

68539450

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

10 PIECE DRAGONFLY SOLAR LED STRING LIGHTS

NEW

LOT 62689
60756 shown

SAVE 76%

\$799
comp at \$34.49

one stop garages

68496430

LIMIT 9 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

12" SLIDING COMPOUND DOUBLE-BEVEL MITER SAW WITH LASER GUIDE

CHICAGO ELECTRIC POWER TOOLS

LOT 69684 shown
61776/61969/61970

Customer Rating ★★★★★

SAVE \$264

\$13499
comp at \$399

68455724

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

AUTOMATIC BATTERY FLOAT CHARGER
CENTECH

Customer Rating ★★★★★

SAVE 82%

LOT 69594
69955
42292 shown

\$599
comp at \$34.99

68449084

LIMIT 8 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

12,000 LB. ELECTRIC WINCH WITH REMOTE CONTROL AND AUTOMATIC BRAKE

SAVE \$453

LOT 61256
60813/61669
68142 shown

\$2999
~~\$3999~~
comp at \$752.99

68495043

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

WOW SUPER COUPON

6.5 HP (212 CC) OHV HORIZONTAL SHAFT GAS ENGINES
LOT 60363/69730/68120
LOT 68121/69727 shown
CALIFORNIA ONLY

Customer Rating ★★★★★

SAVE \$230

\$9799
~~\$11999~~
comp at \$328

68464037

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

RAPID PUMP® 3 TON LOW PROFILE HEAVY DUTY STEEL FLOOR JACK

PITTSBURGH

• Weighs 73 lbs.

LOT 61282 shown
68049/62326
62670/61253

SAVE \$85

\$8499
comp at \$169.99

68458638

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

MOVER'S DOLLY
LOT 60497/61899
62399/93888 shown
• 1000 lb. Capacity

SAVE 56%

\$876
~~\$1100~~
comp at \$19.97

68473898

LIMIT 6 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 5/5/16. Limit one coupon per customer per day.

• 100% Satisfaction Guaranteed • No Hassle Return Policy • 600 Stores Nationwide
• Over 30 Million Satisfied Customers • Lifetime Warranty on All Hand Tools • HarborFreight.com 800-423-2567

VISIT WWW.EHEAT.COM OR CALL 1-800-807-0107

enviTM
WALL-MOUNTED ROOM HEATER



ENERGY SAVING
heats room as little as 4 cents per hour!

ULTRA-SAFE
leave unattended 24/7; cool to the touch

HEALTHY
fanless - doesn't blow dust or dry the air, great for those who suffer from asthma or dry eye

SILENT
fanless design, auto dimming power light

STYLISH AND SLEEK
slim space saving design, 19" w x 22" h x 2" thin!

EASY INSTALL
installs in minutes, no drill required; 6 foot cord
120v & 220v hardwired and plug-in models available

10% off coupon : **PMF810** | 2 or more 15% off coupon: **PMF815** | and get FREE SHIPPING to the continental USA & Canada*



WeatherTech®

New!



Size: 16" x 36"



Sizes: 24" x 39" | 30" x 48" | 30" x 60"

BootTray™ | InDoorMat™ | OutDoorMat™

Available colors: brown, grey, black and tan

WeatherTech.com • 800-441-6287



For US Customers :
WeatherTech.com



For Canadian Customers :
WeatherTech.ca



For European Customers :
WeatherTechEurope.com

©2015 MacNeil IP LLC

CREDITS

p. 3 Christa McAuliffe: NASA; car: Ian Allen; cheerleader: Dina Litovsky; Oscar: Getty Images; p. 4 Ryan D'Agostino: Ida Garland; p. 6 Columbia, TV, Super Bowl 50, race car, fire extinguisher, car battery: Getty Images; Triple 9: Worldview Entertainment; Gods of Egypt: Summit Entertainment; Grammy: iStock; p. 10 Donald Trump, Ben Carson, Hillary Clinton, Bernie Sanders: Getty Images; p. 14 Artists Against ISIS; p. 16 rum bottles: Rusticator Rum, Bully Bros Rum, Twenty Boat Spiced Rum; p. 18 tracking chip: NFL; Levi's Stadium: 49ers; ad: Volkswagen; pp. 27-28 Forest Grove High School; p. 31 Milwaukee saw: Milwaukee Tool; p. 34 eggs, avocado: Getty Images; baking powder: Shutterstock; hammer with tennis ball: Devon Jarvis/Studio D; pp. 38-39 ice chisel: Frabill; Sorel boots: Philip Friedman/Studio D; augers: Jiffy Pro, Ion; p. 54 Challenger comes apart after liftoff: Bruce Weaver/AP Images; VIP stands: Keith Meyers/New York Times/Redux; p. 57 Challenger crew: Steve Helber/AP Images; p. 58 Jay Greene: NASA; p. 61 Ronald Reagan and staff: AP; p. 62 Rogers Commission: Terry Ashe/Life Pictures p. 66 railgun: courtesy of the Navy; p. 67 dump truck: BelAZ; Three Gorges Dam: China Press; p. 68 Bigfoot truck: Peter Taylor; Bigfoot: Patterson-Gimlin Film; p. 69 Kawasaki Ninja bike: Kawasaki; p. 71 extrusion press: Universal Alloy Corporation; p. 72 dung beetle: Minden Images; laser: Lockheed Martin; pp. 74-75 ship engine: Wärtsilä; whale: Getty Images; hovercraft: Griffon Hoverwork; pp. 84-85 Gone With the Wind, Matrix, Toy Story: Everett Collection; Walter Misch and Gregory Peck: A.M.P.A.S.; awards recipients: Gus Ruelas/Corbis; David Gray: Chris Pizzello/AP Images; IMAX camera: IMAX; Steadicam: Garrett Brown; pp. 86-87 Airwall: Aircover; physics simulation system: Odin; Clairmont camera: Clairmont; "An Appreciation": Getty Images; Mad Max: Fury Road: Everett Collection; p. 88 Tangerine: Augusta Quirk; Anomalisa: Paramount Pictures; The Martian: Aidan Monaghan/20th Century Fox; p. 89 The Walk: Everett Collection; Vikander android: A24 Films; BB-8: Disney; camera: Canon.

POPULAR MECHANICS (ISSN 0032-4558) is published monthly except for combined July/August and December/January, 10 times a year, by Hearst Communications, Inc., 300 West 57th Street, New York, NY 10019 U.S.A. Steven R. Swartz, President & Chief Executive Officer; William R. Hearst III, Chairman; Frank A. Bennack, Jr., Executive Vice Chairman; Catherine A. Bostron, Secretary. Hearst Magazines Division: David Carey, President; John A. Rohan, Jr., Senior Vice President, Finance. ©2016 by Hearst Communications, Inc. All rights reserved. Popular Mechanics is a registered trademark of Hearst Communications, Inc. Periodicals postage paid at NY, N.Y., and additional entry post offices. Canada Post International Publications mail product (Canadian distribution) sales agreement no. 40012499. CANADA BN NBR 10231 0943 RT. POSTMASTER: Send all UAA to CFS. (See DMM 7074.12.5); NON-POSTAL AND MILITARY FACILITIES: send address corrections to Popular Mechanics, P.O. Box 6000, Harlan, IA 51593. Printed in U.S.A.

EDITORIAL & ADVERTISING OFFICES:

300 West 57th Street,
New York, NY 10019-3797

SUBSCRIPTION SERVICES: Popular Mechanics will, upon receipt of a complete subscription order, undertake fulfillment of that order so as to provide the first copy for delivery by the Postal Service or alternate carrier within 4 to 6 weeks. >>> Subscription prices: United States and possessions: \$24.00 for one year. Canada and all other countries: \$40.00 for one year.

>>> Should you have any problem with your subscription, please visit service.popularmechanics.com or write to Customer Service Department, Popular Mechanics, P.O. Box 6000, Harlan, IA 51593. Please enclose your mailing label when writing to us or renewing your subscription. >>> Popular Mechanics is not responsible for unsolicited manuscripts or art. None will be returned unless accompanied by a self-addressed stamped envelope.

MAILING LISTS: From time to time we make our subscriber list available to companies who sell goods and services by mail that we believe would interest our readers. If you would rather not receive such offers via postal mail, please send your current mailing label or exact copy to Popular Mechanics, Mail Preference Service, P.O. Box 6000, Harlan, IA 51593. You can also visit <http://hearst.ed4.net/profile/login.cfm> to manage your preferences and opt out of receiving marketing offers by email.

AS A SERVICE TO READERS, Popular Mechanics publishes newsworthy products, techniques, and scientific and technological developments. Because of possible variance in the quality and condition of materials and workmanship, Popular Mechanics cannot assume responsibility for proper application of techniques or proper and safe functioning of manufactured products or reader-built projects resulting from information published in this magazine.

Affordable Hearing Aid Technology Only \$299!

Learn about our great digital technology at an affordable price.

The All New HCX!

- ✓ Digital sound processing chip provides crystal clear sound and makes speech easier to understand without feedback
- ✓ Multiple memory programs adapt to most listening situations
- ✓ Nearly invisible thin tube design
- ✓ Helpful low battery warning so you are never caught unprepared
- ✓ Long lasting size 13 batteries
- ✓ 10 bands of layered noise reduction helps to emphasize voices while balancing out background noise
- ✓ 100% Money Back Guarantee



The HCX™

★ Customer Reviews ★

"I will definitely recommend your company to my patients." - Dr. Arun P.

"I just want to let you know how happy my husband and myself are with his new hearing aids!... - Monique S.

Studies Show: Hearing Aids MAY HELP PREVENT DEMENTIA.

A study by Dr. Frank Lin at John Hopkins University, found that adults with hearing loss are significantly more likely to develop dementia and at a faster rate. Fortunately, the use of hearing aids is an effective way to treat hearing loss and may help you maintain healthy mental activity.

www.AdvancedHearing.com/Dementia



SAVE \$40 ON A PAIR
And Get **FREE** 1 Year Supply Of Batteries*

Digital Hearing Aid Technology... For Only \$299!

All hearing aids work the same way. The **microphone** picks up the sound and sends an electrical signal to the **digital signal processor**. The **digital signal processor** is the "brains" of the hearing aid. It takes the sound it receives and adjusts the sound to amplify important speech sounds as well as filtering out unwanted noise. (To ensure the best in quality, our digital processor is designed and manufactured right here in the **United States**.) Once the processor has amplified the sound, it is passed to the **receiver** (also known as the speaker) which emits a corrected and amplified sound through the **sound tube** into your ear.

Most importantly, your new HCX hearing aids work at a **fraction of the cost** of name-brand hearing aids. In addition to the technical components of the hearing aid, you also have a **volume control** that can be modified with a light touch of the finger. Your new hearing aids come with **3 different audio programs** that help you listen in different sound environments. You will love the Open-fit design, that is so light you probably won't even feel that you are wearing your hearing aids – you'll just be hearing clearly!

You can spend thousands for a high-end hearing aid or you can spend **just \$299** for a hearing aid that just plain works (**only \$299 each when you buy a pair**). We are so sure you will love our product, that we offer a **100% Money Back Guarantee - Risk Free** if you are not satisfied for any reason. It's time to get great digital technology at an affordable price!

BUY A PAIR AND SAVE \$40!

1-877-596-7005

Free 1 Year Supply Of Batteries! ▼

*Use Coupon Code When You Order: **PM62**

(Coupon Code & Price Valid For A Limited Time Only!)



The HCX



US Company
Owned And
Operated

FDA
REGISTERED

Visit and Save: www.AdvancedHearing.com/PM62

Get in your comfort zone.



With a certified outdoor wood furnace from Central Boiler, you'll save money and have peace of mind knowing you're heating your home and more with safe, even, clean and comfortable heat.

Outdoor wood furnaces starting at
\$6,490 (for a limited time).

See your local dealer for details.



CentralBoiler.com
or call 800-248-4681

©2015 Central Boiler • ad7018

SIMPLER, STRONGER FASTER ...than any Hydraulic Log Splitter!

**DR® RAPIDFIRE™
FLYWHEEL
LOG SPLITTER**

NEW Models
Now at Our
LOWEST PRICES EVER!



6X FASTER THAN
HYDRAULIC SPLITTERS!

FREE SHIPPING 6 MONTH TRIAL

SOME LIMITATIONS APPLY

Call for **FREE DVD and Catalog!**

TOLL FREE **800-716-2567**

DRlogsplitters.com



WIDESHoes.COM

**EEE-EEEEEE
SIZES 5-20**

Women's Wide
Shoes, too!

Hitchcock



800-992-WIDE

Hitchcock Shoes • Hingham, MA 02043 • dept. 71C6

SOON THE GOVERNMENT
will enforce the "MARK" OF THE BEAST as
CHURCH and STATE unite!
OFFER GOOD IN USA ONLY
Need your mailing address for FREE BOOKS /DVDs
TBSM, Box 99, Lenoir City, TN 37771
thebiblesaystruth@yahoo.com. 1-888-211-1715.

TerraTrike

Rediscover the joy and freedom of cycling!
FREE CATALOG: 800-945-9910 TerraTrike.com

FREE REPORT

Waterwisdom® **\$15.00 Value**

Truth revealed about distilled, mineral, spring, reverse osmosis, bottled, alkalized & more...

800-874-9028 waterwise.com/pm

UNCLOG DRAINS
with Your Pressure Washer

Get \$10 Off
Gift Code: **PM92**
Limited Time

See it in action! **Clog Hog**

ClogHog.com 877-992-5644

THE \$499 FISHING BOAT

**Fish Anywhere, Anytime!
Easy Carry, Easy Set Up!**

Fish remote ponds and lakes, motor across bays, explore scenic harbors. The Sea Eagle® 9 Fisherman's Dream inflatable boat package includes 2 5' oars, foot pump, nylon carry bag, deluxe inflatable seats, high pressure inflatable floor for easy portability and motormount to take electric motor or 3 hp engine.

Special Sale - NOW \$499 COMPLETE
WITH FREE GROUND SHIPPING
To 48 Contiguous United States

Visit **SeaEagle.com** to order & for more info
or Call for Catalog 1-800-748-8066

SEA EAGLE.com Join us on Facebook SeaEagleBoats

19 N. Columbia St., Dept PM026B Port Jefferson, NY 11777

Homeowner's Crawler Tractor!

NEW Loader! **MAGNATrac® RS1000**

- Compact & Powerful!
- Landscape, Skid Logs
- Dig a pond, Food Plots
- 3yr. HONDA Warranty
- MADE in USA!

FREE Catalog & DVD!
STRUCK 877-828-8323

Use Promo Code: **PM216**

StruckCorp.com/models/rs1000

PRICE • FREE 2-DAY SHIPPING (CONT'L USA) • SHIPS IN ONE BUSINESS DAY • MIRROR POCKETS • FRONT & REAR REFLECTOR STRIPS • PATENT PENDING DESIGN • FREE FABRIC SAMPLE

I THINK I'VE MET MY COVER
—Dodge Challenger owner

Practically custom **SELECT-FIT** outdoor/indoor car covers and **SELECT-FLEECE** indoor car covers are complete kits that include free storage bag, adjustment straps, cable and lock.

Free 2-Day Shipping Code **PM2DAY**

GREAT FIT!
—Mercedes-Benz CLA250 owner —Tesla Model S owner

Outdoor/Indoor **SELECT-FIT** only **\$99.95**
Indoor **SELECT-FLEECE** now **\$139.95**
Get both FIT + FLEECE covers for \$230.00

MICROBEAD
MicrobeadCarCovers.com
888-627-1129
TEXT YOUR YEAR, MAKE AND MODEL TO 617-657-4212 FOR MORE INFO

• LIFETIME REPLACEMENT WARRANTY •



SNOWBALL CATAPULT!

A project to build with your children.

DESIGNED BY JAMES SCHADEWALD

Shopping List

QTY	DESCRIPTION
1	2" x 4" x 8'
1	2" x 3" x 8'
1	T-hinge
1	4" PVC pipe cap
2	No. 2 screw eyes
1	½" conduit tube
1	box No. 8 3" deck screws
1	1¼" drywall screw
1	flat rubber exercise band*

*Available at sporting-goods stores and Walmart. The heavier the resistance of the band, the farther your snowball will fly.

Parts

(see diagram)

	DESCRIPTION
A	2" x 4" x 23" center support with one mitered end
B	2" x 3" x 14" frame braces with one mitered end
C	2" x 3" x 3½" mitered spacer blocks
D	2" x 2½" x 17" catapult arm
E	½" x 6½" conduit tube
F	PVC pipe cap
G	T-hinge
H	Screw eyes

Instructions

● parent only
● parent and kid
● kid only

● **1.** Use a miter saw to cut parts to length and to cut the 45-degree angle on the ends of the A-frame.

● **2.** Place the PVC pipe cap on the end of the throwing arm and drill a pilot hole through it. Secure the cap to the arm with a screw. Attach the T-hinge to the base of the throwing arm. Place a screw eye (H) 13 inches up from the hinge.

● **3.** Clamp the A-frame pieces to the workbench. Using a ½" spade bit and a cordless drill, bore holes for the swing arm through the inner pieces of the frame.

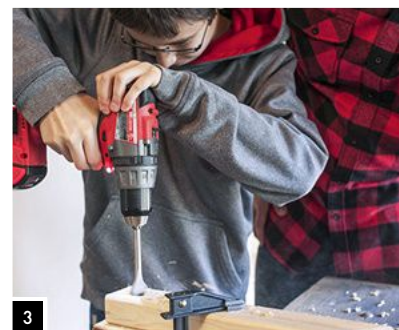
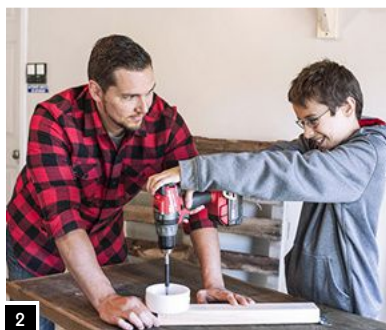
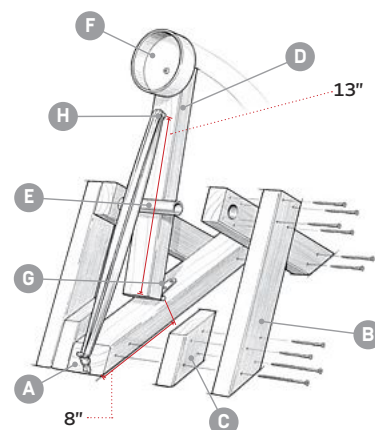
● **4.** Clamp the conduit in a machinist's vise and cut it to length with a hacksaw and fine-

tooth blade. This will connect the top of the frame and serve as a stop for the throwing arm.

● **5.** Assemble the catapult: Screw the hinge (G) into the center support, 8 inches from the mitered edge. Screw together the A-frames, insert the stop (E), and screw the A-frames

to the spacer blocks (C) and center support (A).

● **6.** Attach the second screw eye to the front of the center support. Run the exercise band through the top screw eye and knot it on the bottom. The more taut you make the band, the farther the snowballs will fly.



Turn the page for the finished product



SEE PREVIOUS PAGE
FOR INSTRUCTIONS

OUR BUILDER
Paul Bedoni, 12,
from Pennsylvania.



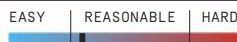
PROJECT NOTES

SNOWBALL CATAPULT!

A project to build with your children.

DESIGNED BY JAMES SCHADEWALD

Difficulty:



Time: 1 hour

Ages: 8+

TO DESIGN THE CATAPULT, first we built a small-scale model out of scrap wood and some leftover parts. It nicely hurled a wad of paper into a wastebasket. Then we scaled up. Too far up, actually. The next version used a throwing arm about 2 feet long and was powered by a thick rubber bungee cord. It was too big to lug to a snowball fight, and way too powerful. We put a plastic action figure in the cup and sent it flying into a neighbor's yard. So we scaled back and settled on the 17-inch arm. We also swapped the bungee cord for an exercise band. (Go for the highest resistance you can find.) It's powerful enough to be fun, but you're not going to hurt anyone.

GIVE

Start a child you know on a lifetime of projects with a gift subscription to Popular Mechanics. Go to popularmechanics.com/gift.

From treehouse to penthouse, we have every saw blade for every project.

Our name says it all

Whatever type of blade you might require, you'll find it at Sawblade.com. All from brands you know and trust, like Q-Saw®, Diablo®, Freud, and Evolution. Whether you're cutting wood, steel, aluminum, tough alloys, or even monel, we are the most complete source – and in fact – the only source for blades you'll ever need.

Find great values everyday at Sawblade.com



Evolution 380 Carbide Saw (includes blade)
\$349.00
(Free shipping)



Trajan 125 Band Saw
\$450.00
(Free shipping)



Diablo Reciprocating 6" Steel Demon Carbide-tipped Blades
10.97 ea.



Q-Saw Wood Blade 7-1/4" x 5/8" x 24T
\$9.30 ea.



Q-Saw Wood Blade 10" x 5/8" x 40T
\$20.35 ea.



Q-Saw Blade for Steel 14" x 1" x 80T (Fits Most 14" Carbide Steel Chop Saws)
\$104.68 ea.



We offer custom-welded band saw blades

- Manufactured with precision ground tooth and spring-tempered backs
- Computer controlled hardening
- Custom welded to any length

SAWBLADE•COM®

Every saw blade for every project.

800.754.6920

Go Further



Ford FORD GT



Preproduction model shown. Available late 2016.